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METALS MAGAZINE

INNOVATION AND TECHNOLOGY FOR THE METALS INDUSTRY

THE ELEMENTAL JOURNEY TOWARD GREEN STEEL

FUTURE-ORIENTED STEEL PRODUCTION WITH ARVEDI ESP

VISITING THE RIO DE JANEIRO COMPANY LOCATION OF PRIMETALS TECHNOLOGIES

PRIMETALS TECHNOLOGIES

Transformational experiences tend to surprise you—by presenting you with a reality you didn't think was possible.

EDITOR'S COLUMN

DEAR READER,

What is the nature of transformational experiences? They usually arrive unexpectedly. As well-prepared for any eventualities as you might be, they will still take you by surprise and lead you into unchartered waters. Sometimes, a seemingly trivial situation can change into something much larger that confronts you with your personal limitations—by presenting you with a reality you didn't even think was possible. These experiences exist to disrupt, but when you embrace them, they can take your thinking and sense-making to a new level.

I believe that, as an industry, we have just entered a transformational period—a time that will bring about deep and lasting change. The transition to green steel production is upon us, with tremendous implications for every one of us, both collectively and individually. It may take us to the limits of what we can deal with. The simple question, "How can we keep making the same steel grades once we've greened our production route?" has the potential for multi-faceted disruption. The same is true for the strategic planning required to get started. Two things are important to remember. First, we are all in this together. It always excites me to see how much creative energy my colleagues at Primetals Technologies are funneling into supporting producers all around the world in upping their game and becoming greener. Second, once we've come out on the other side of the transition, it will have been worth the struggle and the hard work. We will have made a significant contribution to the living standards of future generations. There is no doubt we will get there. For now, I am proud to be part of our mutual, transformational journey to sustainable steel.

DR. TOM WIDTER
EDITOR-IN-CHIEF, METALS MAGAZINE

Yours sincerely,

Dr. Tom Widter
Editor-in-Chief of Metals Magazine
metalsmagazine@primetals.com

36 **WHAT IS GREEN STEEL?**

SPOTLIGHT

TECHNOLOGY

Green steel has taken off—as a commitment, a declaration, and as an indication of where the steel industry is going. But a closer look at "green steel" as a term reveals that producers are thinking of different things.

INSPIRATION

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MESSAGE FROM THE CEO

DEAR CUSTOMER,

Rarely have I felt more strongly about an industry trend than I do about the transition to green steel production. Let me tell you why: At Primetals Technologies, we have always focused on the future—the future of the metals industry and that of our economies and societies. But while it has long been in our DNA to pioneer what's next in the world of steel, our mission has now become even more relevant. We are joining you, our customers, in achieving sustainability on a global scale.

The term "green steel" stands for a kind of product that is seeing increasing demand on the market. Consumers have become more environmentally conscious and expect companies to manufacture their goods as responsibly as possible. Carmakers, for instance, are moving closer to delivering new models that use carbon-neutral steel components. The construction industry is already taking similar steps. And I can't think of any sector that has not started to put major efforts into making its operations and products more compatible with circular-economy principles. It is simply the imperative of our times, and for all the right reasons.

At the same time, "green steel," to my company, is a mission statement that signals our commitment to develop and supply the solutions required to facilitate the transition, which has already begun and will soon be in full force. The coming years will forever change the face of metals production, and everyone at Primetals Technologies is working hard to make a meaningful contribution to the transformation. We strive to be your strategic partner in the transition to green steel—wherever in the world you may be located. There are many aspects to sustainable metals production, from emissions-related initiatives to hydrogen-based production solutions. But wherever the journey to green steel may take you, we will be there for you—with our hearts, our minds, and above all with our technologies.

Yours sincerely,

Satoru Iijima

CEO of Primetals Technologies
and Chairman of the Board

“We strive to be your strategic partner in the transition to green steel production—wherever in the world you may be located.”

Satoru Iijima
CEO of Primetals Technologies and Chairman of the Board

CATCH UP WITH PRIMETALS TECHNOLOGIES

Primetals Technologies supports steel producers everywhere in the world with innovative solutions. Find out how—in our project and company news.

1. Ixtaczoquitlán, Mexico
2. Monroe, Michigan, U.S.A.
3. Pecém, Brazil
4. Bethioua, Algeria
5. Fos-sur-Mer, France
6. Ghent, Belgium
7. Salzgitter, Germany
8. Linz, Austria
9. Tornio, Finland
10. Dilovası, Turkey
11. Mumbai, India
12. Gansu Province, China
13. Pohang, South Korea
14. Okayama, Japan

Geographic locations of the project news topics discussed in this section

Outokumpu trusts the Mold Expert Fiber system to optimize its processes.

Outukumpu's headquarters is located in Helsinki, Finland, with locations worldwide.

OUTOKUMPU BOOSTS QUALITY USING ADVANCED CASTING TECHNOLOGY AT TORNIO SITE

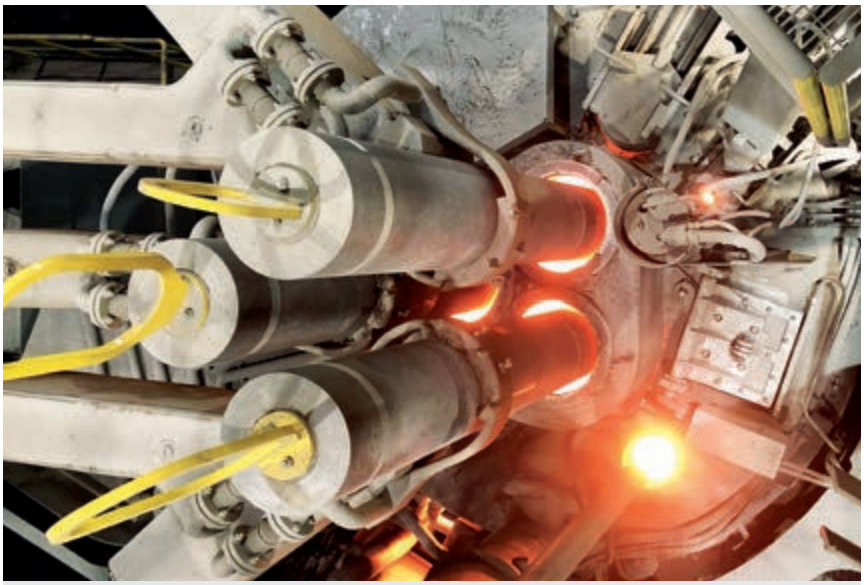
FINLAND: Stainless steel producer Outokumpu has ordered two new slab casting molds and Mold Expert Fiber systems to take its stainless steel casting to the next level. Outokumpu's Tornio site in northwestern Finland will receive the new equipment for its two single-strand slab casters to further optimize production processes and improve product quality. Above all, the Mold Expert Fiber system provides the ability to control the casting process and solidification of the steel to a greater extent. Aimed at warning operators of the potential for a caster-mold breakout as early as possible, Mold Expert Fiber provides data on the exact mold level across the entire mold width and the movement of liquid steel inside the mold. In Tornio, the two new systems will include 1,786 measuring points per mold, which is 30 times more sensors than conventional thermocouple measuring. At the center of Mold Expert Fiber is an advanced technology that involves fiber Bragg gratings, which are burned into the fiber and reflect light. When the temperature changes, they reflect the light differently, and these changes can be measured and visualized.

Twin ladle furnace supplied by Primetals Technologies

TYASA ORDERS NEW TWIN LADLE FURNACE FOR FLATS PRODUCTION

1. MEXICO: Mexican steel producer TYASA signed a contract for a new twin ladle furnace for its Ixtaczoquitlán site in southeastern Mexico. Entering the market for flat products, TYASA set up an additional production route in 2014. Primetals Technologies has supplied the complete minimill, including an EAF Quantum, a twin ladle furnace, a vacuum degasser, a continuous casting machine, and a reversing cold-rolling mill. TYASA also added a CASTRIP production line for coils in 2018. Geared toward increasing capacity at the secondary-metallurgy stage in the meltshop, the new twin ladle furnace will significantly add to the performance of the steel plant. The entire procedure will be optimized and include the replacement of existing equipment and the inclusion of Level 1 and Level 2 automation. Integrating the new 100-ton twin ladle furnace will involve only minimal shutdown time, and just minor modifications will be needed to incorporate the new equipment into the existing dedusting and water treatment systems. Primetals Technologies has created this twin ladle furnace as a tailor-made solution. It was specifically designed to require minimal space in the plant and to allow for the future installation of a twin vacuum degasser capable of using some of the same logistics infrastructure.

The LiquiRob robotic system improves safety by removing human operators from dangerous tasks, combining with comprehensive automation systems for further improvements.



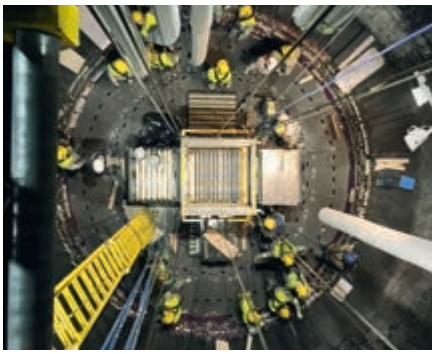
Electric arc furnace operated by Gerdau Special Steel North America at the company's electric steel plant in Monroe, Michigan, U.S.A.

GERDAU SPECIAL STEEL GRANTS FAC FOR ELECTRIC STEEL PLANT IN MONROE

2. U.S.A.: Gerdau Special Steel North America has granted the final acceptance certificate (FAC) for the modernization of its electric steel plant in Monroe, Michigan, U.S.A. The engineering and supply of the project included the modernization of the existing electric arc furnace and the addition of a new 110-ton twin ladle furnace, a new material handling system, and related auxiliary equipment. Investment in the health and safety of its employees was also a priority for Gerdau. The LiquiRob robotic system improves safety by removing human operators from dangerous tasks and combines with comprehensive automation systems. In total, the modernization project included a complete end-to-end process-automation system, three LiquiRob systems, electrical installations, and power supplies. The newly automated features are optimized for improved performance.

NEW RELINING MACHINE FOR CSP'S 300-TON CONVERTERS IN PECÉM

3. BRAZIL: Brazilian steel producer Companhia Siderúrgica do Pecém (CSP) ordered a new relining machine for its steel plant located in Pecém, Ceará, in northeastern Brazil. With two 300-ton converters (BOFs), the expected gains in relining efficiency and safety will immediately lead to greater plant performance. The new mechanism will increase CSP's capacity by approximately 30 percent using a unique patent-pending procedure. The novel relining method circumvents the BOF's fixed bottom, bringing bricks and stirring plugs into the converter via an elevator. Adjustable to any relining position and with a flexible working platform, materials are transported to the platform easily and efficiently. Moreover, the relining machine is movable and can be used with both converters.



The custom-made BOF relining solution of Primetals Technologies in operation.

TOSYALI TO EXPAND IN ALGERIAN MARKET WITH SECOND SLAB CASTER FOR BETHIOUA PLANT

4. ALGERIA: Toysiali ordered a new slab caster for its production site in Bethioua, Algeria. The company chose Primetals Technologies based on successful earlier projects—which include the implementation of two EAF Quantum electric arc furnaces, a twin vacuum-degassing plant with oxygen blowing, and a 2-strand slab caster for the plant in Iskenderun, Turkey. The new 2-strand slab caster will feature advanced Level 2 automation, the Flow Master electromagnetic stirring and braking system, and Through-Process Optimization. The "Connect and Cast" principle will ensure a short and highly effective startup phase.

GRAVITHY LAUNCHED BY WORLD-CLASS CONSORTIUM TO IGNITE GREEN HYDROGEN ECONOMY

5. FRANCE: The consortium behind GravitHy—consisting of EIT InnoEnergy, Engie New Ventures, Forvia, Groupe IDEC, Plug Power, and Primetals Technologies—aims to produce direct-reduced iron from green and low-carbon hydrogen in the south of France. The project plans to mobilize 2.2 million euros of initial investment, create more than 3,000 jobs, and contribute to Europe's "Fit for 55" program. Combining competencies from across the globe, GravitHy anticipates an annual throughput of two million tons of green direct-reduced iron.

STEELANOL CARBON CAPTURE AND UTILIZATION TECHNOLOGY NOW AT MARKET-READY STAGE

6. BELGIUM: On December 8, 2022, ArcelorMittal—together with LanzaTech, E4tech, and Primetals Technologies—hosted an inauguration ceremony for the Steelanol plant located nearby ArcelorMittal's steel plant in Ghent, Belgium. The four stakeholders had partnered to develop the plant, which is now fully operational, in 2014. Utilizing the off-gas from the blast furnace, the Steelanol plant produces ethanol, which can be used for sustainable aviation fuel, packaging, textile production, and even perfumes and household products. Every ton of ethanol produced will reduce carbon emissions by 2.3 tons. This type of plant is expected to pay for itself within three to five years.

SALZGITTER ORDERS EAF ULTIMATE FOR GREEN TRANSITION

7. GERMANY: Salzgitter has affirmed its commitment to low-carbon steelmaking after investing in transforming its integrated steel plant into a highly efficient direct reduction and electric steelmaking plant. The Salzgitter Low CO_2 Steelmaking (SALCOS) project will amount to two direct-reduction plants and three electric arc furnaces to replace the existing blast furnaces and converters. The transformation has begun with the recent order of an EAF Ultimate with a tapping weight of 220 tons and an annual capacity of 1.9 million tons of steel. The EAF Ultimate at Salzgitter will feature dust removal systems, a heat recovery system, a water management system, electrical compensation for grid stabilization, and material handling for alloying material and additives. It will also include Level 1 and 2 automation systems and the LiquiRob robotic system.

INDUSTRIAL SCALE GREEN IRONMAKING PIONEERED IN LINZ

8. AUSTRIA: Fortescue and voestalpine have joined Primetals Technologies, together with Mitsubishi Corporation, by signing a Memorandum of Understanding to design and engineer an industrial-scale prototype plant for green ironmaking in Linz, Austria. The plant aims to direct-reduce iron ore fines utilizing hydrogen and to further reduce those fines in a Smelter for the production of green hot metal. The HYFOR and Smelter solutions from Primetals Technologies form the basis of the prototype plant and draw on the raw-material expertise of Fortescue and the steelmaking and technology experience of voestalpine. The target for the design of the prototype plant is three to five tons of green hot metal per hour. After successfully implementing a prototype plant, each partner will gain the knowledge required for a full-scale commercial plant. The hydrogen supplied to the prototype plant will come from Verbund, Austria's leading renewable energy producer, which runs the H2Future proton exchange membrane electrolyzer in Linz. This project aligns with voestalpine's plans to decarbonize steel production with its "greentec" program, focusing on a shift away from the blast furnace toward a hybrid-electric pathway. Fortescue Future Industries is leading the green industrial revolution, developing solutions for hard-to-decarbonize industries, and building a portfolio of renewable energy, green hydrogen, and green ammonia projects.

A view of the 2-strand caster at Çolakoğlu's record-setting plant in Dilovası, Turkey

ÇOLAKOĞLU SETS TWO WORLD RECORDS IN STAINLESS STEEL

10. TURKEY: Located in Dilovası, about 40 miles southeast of Istanbul, Turkish steel producer Çolakoğlu set two world records with its vacuum oxygen decarburization (VOD) plant, which was supplied by Primetals Technologies. The VOD plant is one of the world's largest and was designed to support enormous throughput: the record-breaking heat size of 298.2 tons effectively doubles the heat sizes of typical VOD plants, which range between 60 and 150 tons. The process parameters at Dilovası allow for tapping at high temperatures and prevent any clogging issues, panel leakage, and refractory problems. The VOD system uses a degassing unit equipped with an oxygen-blowing lance, vacuum-pump regulation for oxygen-blowing conditions, and other components, such as gas cooling, dust filtering, and CO-burning systems. Using the additional oxygen supply, the VOD plant can produce extra-low-carbon stainless steel grades and chemically heats the melt in conjunction with the addition of aluminum or silicon. Thanks to the advanced characteristics of the VOD plant, Çolakoğlu obtained a carbon content of five parts per million after decarburization, a record-setting measurement for stainless steel. Çolakoğlu's strategic aim is to help compensate for Turkey's trade deficit by replacing imports.

Turkish steel producer Çolakoğlu achieved a heat size of 298.2 tons at its VOD plant.

PARTNERS IN GREEN STEEL AND DECARBONIZATION: TATA STEEL AND PRIMETALS TECHNOLOGIES

11. INDIA: Tata Steel and Primetals Technologies signed a Memorandum of Understanding in Mumbai, India, to intensify their collaboration on green steel and decarbonization projects. One of the largest steel producers in the world, Tata Steel—including the company's subsidiaries, associates, and joint ventures—maintains an annual production capacity of approximately 34 million tons of crude steel. Having set the goal of reaching carbon neutrality by 2045, Tata Steel chose Primetals Technologies, the pioneer in sustainable steel production, to support its decarbonization efforts. The broad portfolio of Primetals Technologies in green steel was a motivating factor for Tata Steel—for instance, solutions for decarbonization, emissions reduction, energy efficiency, as well as technologies to improve recycling capabilities that reduce waste and increase yield. These innovations include hydrogen-based ironmaking, electric steelmaking, endless casting and rolling, and carbon capture, utilization, and storage, thanks to Mitsubishi Heavy Industries Group. With a strong focus on decarbonization and investments to support global climate action, low-carbon and carbon-neutral steel production will be necessary for a sustainable future. Tata Steel's commitment reflects a worldwide trend toward a sustainable steel industry with an emphasis on eco-friendlier production routes that reflect the recyclability of steel as an essential material for a sustainable society. Moreover, the Memorandum of Understanding underscores the global nature of climate change, as Tata Steel's role as a steel producer with operations and commercial presence worldwide couples with the international presence of Primetals Technologies, along with engineering expertise and proven eco-friendly solutions.

A copper rod mill from Primetals Technologies

SOUTHWIRE COMPANY TO SUPPLY THIRD SCR COPPER ROD MILL TO JINCHUAN GROUP

12. CHINA: Southwire Company has tasked Primetals Technologies with the supply of rolling mill equipment for a new Southwire Continuous Rod (SCR) copper rod system, which will be used by Jinchuan Group Company in Gansu Province, China. The new system marks the third SCR copper rod system for Jinchuan, strengthening its long-term business relationship with Southwire and Primetals Technologies. The new rolling mill will produce electrolytic tough pitch copper in the form of wire and cable for the construction industry. Founded in 1958, the state-owned enterprise Jinchuan is the fourth-largest copper producer in China. The Southwire SCR 7000 rolling mill includes a Morgan NO-TWIST mill with high load capacities of up to 48 tons per hour. Southwire's SCR process makes up 50 percent of all copper rod production worldwide. This new project is the latest chapter in Southwire's long-standing partnership with Primetals Technologies regarding implementing and upgrading new and existing SCR systems.

DEMONSTRATION PLANT FOR HYREX FROM POSCO

13. SOUTH KOREA: POSCO and Primetals Technologies signed a Memorandum of Understanding to develop a demonstration plant for hydrogen-based hot metal production. The innovative process employed at the plant is called "HyREX" and uses hydrogen to produce direct-reduced iron from sinter fines, avoiding agglomeration. HyREX builds on the collaborative history between POSCO and Primetals Technologies, including the development and operation of a commercial FINEX plant, which relies on an ironmaking process using iron ore fines and non-coking coal. The new hydrogen-based process is integral for POSCO to achieve carbon neutrality by 2050. The development and construction of a HyREX plant is part of POSCO's plan to assess hydrogen-based direct reduction and methods to produce hot metal without blast furnaces. Dr. KiSoo Kim, Head of Low Carbon Process Research and Development at POSCO, notes: "For the development of eco-friendly hydrogen-based hot metal production, collaboration across all sectors such as raw materials, engineering, and hydrogen is essential."

HyREX, the new hydrogen-based hot metal production process, is integral for POSCO to achieve carbon neutrality by 2050.

TOKYO STEEL ISSUES FAC FOR CONTINUOUS PICKLING LINE

14. JAPAN: Tokyo Steel has issued Primetals Technologies with the final acceptance certificate (FAC) for a revamped continuous pickling line for hot-rolled strip in Okayama, Japan. The revamp project included the installation of a polypropylene iBox pickling tank with the Acid Concentration Control System and a 50-ton tension leveler-type scale breaker. The project coincides with the long-term environmental vision "Tokyo Steel EcoVision 2050," focusing on steel production with a low carbon footprint via scrap-based electric steelmaking, increased circularity, and improved energy efficiency. Part of this vision is also a reduction in carbon emissions from the entire production process. The iBox—and the Acid Concentration Control System—improve production capacity during hot descaling while simultaneously reducing energy consumption. The iBox increases energy efficiency by removing an electric pump previously required to circulate the acid solution. The Acid Concentration Control System regulates the acid supply in each tank by using a proprietary algorithm developed by Primetals Technologies to predict and calculate the descaling distribution and pickling reaction, improving the pickling process and reducing waste. Tokyo Steel has maintained its position as the top producer of H-beams in Japan for the past eight consecutive years. The company's initiative to reduce carbon emissions and focus on green steel reflects increased environmental awareness from the steel industry and a trend toward scrap-based electric steelmaking in Japan.

THE ELEMENTAL JOURNEY TOWARD

GREEN STEEL

Recognizing the global trend toward decarbonization, emissions control, and e-mobility, Primetals Technologies is supporting the world's steel producers in their ambition to make green happen.

Green steel is here, and it is here to stay. As consumers around the world increasingly gravitate toward a more environmentally conscious lifestyle, they more regularly choose products that were made with the planet's future in mind. E-mobility is only one—albeit important—example that underlines the larger trend. The growing adoption of electric cars, which are made using advanced high-strength and silicon steels, illustrates an important aspect of how the metals industry is contributing to greater sustainability. Another important factor is decarbonization.

For steel producers, the goal of manufacturing green steel is an obvious one. However, the precise meaning of the term "green steel" is still being debated. While producers have begun crafting their own definitions (see pgs. 36–39), they vary considerably depending on the region a producer operates in, the products they make, and the markets they are in. What's clear is that everyone targeting green steel is determined to take their operations to the next level, develop their portfolio, and stay ahead of the curve that leads to a greener tomorrow.

DEFINING "GREEN STEEL"

To Primetals Technologies, green steel is two things. First, it is an umbrella term for steel products that point the way to a more sustainable future. Gradually, green steel will be carbon-neutral—even if it takes time to get there. Emissions other than CO_2 play an equally crucial role, from dust to dioxins and heavy metals to sulfur and nitrogen oxides. And last but not least, products labeled as "green steel" must be designed to support the circular economy and to improve the long-term prospects of the societies we live in.

Second, green steel is also a mission statement. It is the commitment of Primetals Technologies to engineer and supply new and advanced solutions to steel producers—solutions that will enable the transition to a greener future of metals production. But what will this future look like? It will see steel producers rely on renewable energy sources such as green electricity and hydrogen. The electric steelmaking route will be replacing or enhancing the integrated production route. Direct reduction will play a significant role. And digital solutions designed to orchestrate the many processes taking place in a plant will enable producers to transform and fine-tune their operations whilst keeping plant downtime and product-development efforts minimal.

AN ELEMENTAL MISSION

For everyone at Primetals Technologies, "making green happen" is an elemental objective. There is a direct connection between steel production and nature itself: they both trigger a feeling of awe—whether you encounter one of the world's breathtaking natural phenomena or unleash the raw power of the metallurgical processes involved in the production of the world's most recyclable material. Both nature and metallurgical processes carry a might of their own. They give us the sense that we are dealing with something larger than ourselves. They give us a sense of purpose and belonging. And they put us in touch with the universal essence of the elements: earth, fire, water, and the winds.

Just as nature can only exist as a combination of all four elements, the mission to realize green steel hinges on the interplay of many contributing factors that form one cohesive union. Primetals Technologies takes a holistic view of environmentally compatible steel production and develops new solutions to support and ease the transition to green steel. This makes its experts the partners of choice for steel producers sharing the same ambition: to become a catalyst for change, to take responsibility for future generations, to contribute to the sustainability of industrial production, and, finally and decisively, to make green happen.

RAW-MATERIAL PROCUREMENT & MANAGEMENT

Earth in many ways is the most fundamental of the elements. It is the origin of all matter, the genesis and the destiny of all things. This is not only true for nature, where seeds sprout to grow into flowers, crops, and trees. It also applies to steel production, which depends on raw materials—on matter taken from the earth—to unleash the power of its processes, turning ore into iron and steel.

As the transition to green steel takes hold, the question of which raw materials to rely on becomes an elemental one. Gone are the days when the integrated production route dictated the use of coal and coke in ironmaking. Fossil fuels on the whole are bound to gradually leave the stage. But iron ore will remain an important raw material for the foreseeable future, even if certain kinds of ore are becoming increasingly scarce. The grain size of the ore sourced from deposits around the world varies, requiring different reduction techniques; Primetals Technologies offers solutions that cover them all. This includes direct-reduction solutions provided in collaboration with Midrex Technologies as well as HYFOR, the hydrogen-based fine-ore reduction innovation that is currently being developed by Primetals Technologies in Austria. As the industry moves toward the circular economy, it is starting to explore new and innovative ways to obtain raw materials. One example is the Zinc Extraction Process (ZEP), which is capable of recycling zinc, iron, and valuable minerals from the off-gas dust generated by electric arc furnaces. Processes like ZEP will become ever more important as electric steelmaking begins to play a more dominant role, thanks to the increased use of scrap as a raw material. As a result, smart scrap-processing technologies will become a must for many producers on the journey toward green steel.

SCRAP PROCESSING TECHNOLOGIES

With electric steelmaking on the rise, the emphasis on scrap as a "raw material" is becoming more pronounced. Scrap has long served as an input material for rebar producers with minimill setups. Producers of high-end steels such as advanced high-strength steels or pipe grades have, however, largely depended on the integrated production route to reach the desired quality levels. These producers are now starting to add electric arc furnaces to their plants and require "crafted scrap" (see pgs. 54–57)—which is scrap with much fewer tramp elements like copper, plastics, and phosphrous—to maintain end-product quality. Primetals Technologies, in addition to its own solutions, is offering advanced scrap processing technologies together with partner company SICON.

DIRECT REDUCTION SOLUTIONS

The future of ironmaking is also significantly greener thanks to the availability of direct reduction technologies for every type of iron ore—all of which can be powered by low-carbon hydrogen. The direct reduction solutions provided by Primetals Technologies in collaboration with Midrex Technologies belong to this group of ironmaking innovations. Today, they operate using natural gas, but before too long they will switch to hydrogen as the main reducing agent. Direct reduction solutions are ideally built in regions that lend themselves to the production of cheap renewable energy, such as the Middle East, North America, and Australia. The availability of quality iron ore is certainly also crucial, but abundant green energy will likely become the key differentiator.

HYDROGEN BASED FINE ORE REDUCTION

Hydrogen-based Fine-Ore Reduction (HYFOR) is the world's first direct reduction process for iron ore fines that does not require any preprocessing of the material like sintering or pelletizing. HYFOR is currently at an advanced stage of development with a fully functional pilot plant in Donawitz, Austria, and the next step in upscaling the technology to an industrial prototype is already around the corner. HYFOR builds on the experience Primetals Technologies gained from creating the Finored and Finex processes, and can be used with any type of beneficiated ore. HYFOR dramatically reduces carbon emissions, making a potentially massive contribution to the future of green steel. It also addresses the global challenge of limited supplies of high-quality iron ore.

THE ELEMENT OF FIRE

NEXT GENERATION UPSTREAM TECHNOLOGIES

Fire represents the untamed energy required for life to find its way into this world. It is the archaic force behind natural phenomena such as volcanic eruptions and geysers. It also comes into play in steel production, where many upstream processes run at temperatures of 1,000 degrees Celsius or more. Compare a stream of lava to the glowing stream of liquid steel during blast furnace tapping—or a lightning strike to the rolling thunder coming from an electric arc furnace. The world of metals could not exist without the element of fire.

When making green steel production happen, the upstream area is the main target for taking action, certainly in terms of carbon emissions and energy efficiency. This simply has to do with the temperatures involved in virtually all reduction processes in ironmaking and treatment steps in steelmaking. A traditional production route also involves several stages that necessitate reheating—the less often this occurs, the better. Arvedi Endless Strip Production is a solution that takes energy efficiency seriously, with a dramatic reduction in carbon emissions compared to a traditional production line that covers casting and rolling. Arvedi ESP is ideally combined with a power-saving electric arc furnace, such as Primetals Technologies' EAF Quantum. The EAF Ultimate, which is compatible with high-end steel production, will also address the issue of increased relevance of electric steelmaking and corresponding capacity targets. While EAFs will happily accept scrap or quality hot-briquetted iron as feed material, other types of input material can prove problematic due to a higher proportion of impurities. In such cases, a Smelter—another technology showcasing the element of fire—can be the ideal solution. It removes the slag portion from the raw material so that the subsequent furnace can apply its force.

ELECTRIC STEELMAKING TECHNOLOGIES

Even though many producers of top-level steel grades are currently relying on integrated steel plants, this is bound to change. Electric steelmaking (see pgs. 58–63) has the benefit of being much greener—in terms of circularity and emissions. Compared to the production route that includes a sinter plant, blast furnace, and basic oxygen furnace, the electric steelmaking based route is in a completely different league regarding environmental compatibility—especially if the electric arc runs on green electrical energy. Primetals Technologies offers different electric arc furnaces to cover all possible use cases: from the energy-saving EAF Quantum to the EAF Fusion with its adaptive raw-material mix and the uniquely powerful EAF Ultimate, the range of furnaces is unparalleled.

ENDLESS CASTING AND ROLLING

Arvedi Endless Strip Production (ESP) is the world's only truly endless thin-slab casting and rolling solution. Its innovative design allows it to operate at a zero-carbon footprint (based on "Scope 1" calculations, see pgs. 64–71). Arvedi ESP minimizes the need for reheating the steel after casting and produces hot-rolled coils on par with traditionally cold-rolled strip. The resulting "direct-application" steel is a desirable base material for manufacturers of automotive components and structural steel products, among others. Arvedi ESP's product range includes ultra-low- to high-carbon steel grades, high-strength low-alloyed grades, advanced high-strength steels such as multiphase, and various alloyed—for instance silicon—steels, at strip thicknesses from 0.6 to 25.4 millimeters.

SEQUENCE IMPULSE PROCESS

The road to green steel is one that many producers prefer to go down gradually, making incremental changes to their plants to lower their carbon footprint step by step. The newly developed Sequence Impulse Process (SIP) optimizes the injection of oxygen and coal into the blast furnace, thereby improving furnace performance and process stability. It works by superimposing periodic bursts of oxygen on the steady flow of hot air to the blast furnace, which leads to a better conversion behavior of coal particles. Not only does SIP represent a significant step toward greener ironmaking, but it also makes great economic sense: SIP typically pays for itself within a 12-month period, and the reduction in carbon emissions also means lower tax-related costs.

COOLING SOLUTIONS & CIRCULAR ECONOMY

Water is the element required to sustain life. It helps to balance the raw force of nature—Fire—with calm and restraint. Lava beaches, such as the ones found on the Canary Islands, are a manifestation of this balancing act, as they result from the ocean meeting the power of the Earth's hot, liquid core. In metals production, water plays a similar role. It equalizes the heat stemming from many upstream processes. It is also a catalyst and change agent—the medium without which many green technologies could not exist.

The transition to the electric steelmaking route has implications not only for iron- and steelmaking but also for later steps in the production chain. A change in the raw-material mix, for instance, a higher proportion of scrap, necessitates adjustments in continuous casting and at various cooling stages, so as to ensure that the surface quality of the cast and rolled products remains at the same high level previously achieved with integrated steel production. Water—correctly and thoughfully distributed—is the medium any advanced cooling strategy depends on. But the journey to green steel goes far beyond decarbonization and the shift to electric steelmaking. Making metals production more sustainable also involves solutions geared toward realizing the circular economy—for example, By-Product Leaching plants and water-treatment plants, which Primetals Technologies has extensive experience with as some 200 plants have been sold to date. Heat recovery systems are equally relevant and often rely on water to absorb the enthalpy from hot waste gas and put the energy to use in a different area of the plant. In this process, water turns to steam and carries all the energy required to power additional plant equipment, leading to significant cost savings.

BY-PRODUCT LEACHING PLANTS

Thanks to advances in off-gas cleaning, steel producers have the technologies required to capture up to 99 percent of potentially harmful emissions stemming from their sinter and pelletizing plants, blast furnaces, converters, and other production units. One such technology—arguably the best available one—is the MEROS system (see pg. 27). But while the primary result is clean air, the question remains: what is to be done with the substances that were removed from the off-gas? This is where By-Product Leaching plants come in: the world's first was started up in 2020 and now recovers up to 90 percent of the valuable materials like iron, lime, and carbons for reuse and recycling. Just like MEROS, this innovation fulfills "best available technology" requirements.

ADVANCED COOLING SOLUTIONS

Thanks to continual development, the cooling solutions of Primetals Technologies have become even greener and more efficient, and also help producers to increase yield. Advanced cooling models precisely predict how much water will be required for at the cooling stages. Correctly controlled and distributed cooling also facilitates the transition to electric steelmaking, since the change in raw materials requires smart adjustments in later production steps to ensure the same end-product quality as formerly achieved via integrated steel production. The Power Cooling solution significantly reduces the need for expensive micro-alloying elements as it practically enables "alloying with water," with higher cooling rates realizing the desired mechanical properties of the strip.

HEAT RECOVERY SYSTEMS

Energy savings are not only economically desirable as they lower overall production cost—they also contribute to making green steel a reality. Heat recovery systems should ideally be implemented in all areas of a steel plant that involve high-temperature processes. They often rely on water to absorb the enthalpy, move the energy away from the source, and make it usable for other purposes, such as powering additional plant equipment. One example that highlights the benefits of a high-end heat recovery system is a Primetals Technologies implementation at the site of Italian producer Acciaieria Arvedi. The system was designed to recover waste heat from the plant's electric arc furnace and generates enough steam to power three pickling lines.

EMISSIONS CONTROL & CARBON-RELATED TECHNOLOGIES

Air is the invisible element, but humans, animals, and plants nonetheless depend on it. Without it, the element of fire—so crucial for everything from sunlight to metals production—would cease to exist. Air must not be overlooked, and indeed, it has received more global attention of late as efforts to tackle emissions directly or indirectly address the quality of the air we breathe each day.

When it comes to emissions, carbon dioxide is currently dominating the conversation. Most of the world's climate scientists conclude that the human factor is playing a critical role in global warming and that corrective action is overdue. Part of the solution is a reduction in carbon emissions on the production side, and Primetals Technologies has developed solutions that will bring about lasting change, especially in the upstream area (see "Fire" and "Earth"). But innovations in the field of carbon capture, utilization, and storage are important additions to the long-term decarbonization strategy of many sectors, including the metals industry. But air quality—and emissions—do not solely depend upon carbon neutrality. Dust, dioxins, heavy metals, sulphur and nitrogen oxides, and organic compounds were traditionally also emitted into the atmosphere during steel production, causing environmental impact. Solutions such as the MEROS off-gas cleaning system have successfully taken care of this problem, achieving a 99 percent reduction in emissions of potentially harmful substances. Even though MEROS was initially designed to work with sinter and pelletizing plants, the technology has since been adapted for use with power plants and in the iron- and steelmaking stages (MERIM and MERCON, respectively). Sinter plants remain an important target, and advanced waste-gas recirculation solutions are making their contribution to increased energy efficiency.

MEROS OFF-GAS CLEANING

Historically, sinter plants were often regarded to be among the most environmentally problematic production units of a steel plant. Sinter plant off-gas contained large amounts of dust, sulfur and nitrogen oxides, heavy metals such as mercury, cadmium, and lead, as well as potentially harmful organic compounds. Wet dedusting technologies were developed and implemented, but those generated new challenges like water pollution. MEROS changed all that: a dry-dedusting solution and a "best available technology," MEROS removes up to 99 percent of the relevant substances, which can then be recycled and reused via the By-Product Leaching process. Currently, no fewer than seven MEROS units are being implemented at an Italian steel plant (see QR code).

SELECTIVE WASTE-GAS RECIRCULATION

The Selective Waste-Gas Recirculation system optimizes a sinter plant's energy consumption. It also reduces the volume of waste-gas that needs to be cleaned by choosing which portion of the waste gas to re-introduce into the sinter strand. Different wind boxes can be selected for recirculation. Only a small quantity of fresh air needs to be added to the recirculation-gas stream to ensure the oxygen content required for the production of high-quality sinter. The recirculated gas is sent through the sinter strand, which acts as an additional filter and utilizes the carbon monoxide and heat as energy sources. The result is a lower coke consumption in the sintering process and a reduction in sulfur dioxide and carbon emissions, as well as other harmful substances.

CARBON CAPTURE, UTILIZATION, AND STORAGE (CCUS)

Primetals Technologies is pioneering carbon capture and utilization in metals production via its participation in LanzaTech's gas fermentation effort. The solution, which Primetals Technologies is co-developing as a project partner, uses microbial fermentation of carbon- and hydrogen-rich waste-gases to produce biofuel and other basic chemicals. This process works with blast-furnace top gas, coke-oven gas, and off-gases from converter steelmaking and direct reduction. Since Primetals Technologies is part of the larger Mitsubishi Heavy Industries Group, it is in a unique position to move the world of metals production further toward green steel, thanks to MHI's expertise and already decades-long experience in the field of carbon capture with the proven KM CDR process.

THE CORE

THREE LAYERS OF STRATEGIC CONSULTING

The Core represents the unifying principle that encompasses all of nature's elements—and all technologies paving the way toward green steel. Strategic consulting helps producers to identify which measures to take in order to reach certain goals. The ultimate ambition may be clear—fully environmentally compatible steel production that targets future-oriented markets—but it takes a systematic approach to achieve this goal.

BUSINESS & PORTFOLIO DEVELOPMENT

The transition to green steel is affecting different producers in different regions in different forms. The strategy experts at Primetals Technologies are used to taking a holistic view and can support producers in making portfolio- and market-related decisions. Once these decisions have been taken, choosing the correct technologies to realize the new goals becomes much easier. For example, a producer may want to optimize their portfolio toward greener, high-margin steels for the automotive industry. Another producer may be looking to keep their portfolio unchanged and to optimize the production route for reduced carbon emissions. Depending on the current plant configuration and the country they operate in, the recipe for success will vary. Primetals Technologies can provide guidance throughout the entire decision-making process.

DEFINING THE PRODUCTION ROUTE

Having determined the fundamental strategy, the next step is to define precisely which technologies will be required to facilitate the intended transformation. Tools such as the Carbon Calculator, recently developed by Primetals Technologies, provide producers with specific and detailed information. The Carbon Calculator allows users to design custom production routes. The calculator then computes the approximate amount of carbon dioxide generated by the respective production chain. Primetals Technologies also offers expert advice that will refine a producer's core strategy.

LOGISTICS AND YIELD OPTIMIZATION

The third layer of strategic consulting concerns the optimization of the new plant layout and the elimination of bottlenecks. Surprisingly often, even small modifications to the interplay of different parts of the production chain yields huge productivity gains. Especially greenfield projects and extensions but also changes to existing production lines benefit from a thorough analysis of the logistics setup. Is all steelmaking equipment in the optimal place to uninterruptedly serve the continuous casters? Do the cranes have the space they require to complete their tasks in time? Resolving questions like these often leads to significantly greater plant capacity.

MAKING **GREEN STEEL HAPPEN**

Dr. Alexander Fleischanderl is one of Primetals Technologies' chief innovators in the area of sustainability solutions. He pioneered the MEROS off-gas cleaning system, which has been sold 15 times thus far, and continues to extend the green production portfolio at Primetals Technologies. Fleischanderl was recently promoted to "Head of Green Steel"—a new role that will allow him to make an even larger contribution to the long-term sustainability of metals production.

How do you define your new role at Primetals Technologies as "Head of Green Steel?"
Dr. Alexander Fleischanderl: It's still early days for "Green Steel," but it clearly is a topic of great complexity with many dimensions. It covers everything from the generation of renewable energy and energy storage solutions—including hydrogen and ammonia production—to the optimal use of these energy sources for the actual production of green steel. The availability and variable quality of raw materials further adds to the complexity of the subject matter: supplies of quality scrap are limited, and the same is true for high-grade iron ores. There are many stakeholders involved, and therefore it will be part of my role to consider all their different standpoints and experiences. Based on that, I will be establishing a holistic approach. My aim is to develop a cohesive strategy that takes into account all the relevant steps from basic R&D work to policy to strategy to concrete project development. The steel industry is already on the journey to green steel, and I believe my team and I will be making a substantial contribution.

Will steel production ever truly be zero-carbon?
Fleischanderl: Fundamentally speaking, because of the material properties of steel, it will never be "zero-carbon." However, we are indeed aiming for a dramatic reduction in carbon emissions stemming from steel production, particularly in the upstream area. I am confident that, together with our customers and industry partners, we will reach this goal sooner rather than later. Even today, it is theoretically possible to engineer and build steel plants capable of producing ultra-low-carbon-emissions steel. The only thing keeping us from doing so is the availability—and viability—of renewable energy, meaning green electricity and hydrogen. These energy sources require massive upscaling, which will happen.

How will digital solutions contribute to green steel?
Fleischanderl: Digital technologies play an integral role in our decarbonization efforts. Digital twins can help to optimize production processes—by increasing energy efficiency, reducing yield loss across the entire production chain, easing the development of new steel grades, and by calculating carbon emissions per production unit and for every single coil. In essence, digitalization is all about optimizing the complete production chain for efficiency, because it allows us to fine-tune and orchestrate all production-related aspects. Digital tools are also essential for preserving the knowledge of a plant's metallurgists and experienced operators. As an ultimate goal, I envisage the "autonomous plant", and I believe that this vision is not as distant as it may seem.

STEP BY STEP TOWARD DECARBONIZATION **THE PATH FORWARD**

HOW WILL THE STEEL INDUSTRY TRANSFORM?

With its high strength-to-weight ratio and relatively low production costs, steel's recyclability makes it invaluable for the development of society toward sustainability. However, the steel industry currently carries a heavy burden, contributing around eight percent of global carbon emissions. With carbon-neutral targets set by 153 countries, the pressure is on reducing carbon emissions and moving away from fossil fuels. The steel industry has transformative innovations to reach green steel production.

Green steel has arrived. A term that is becoming commonplace in the steel industry, "green steel" represents a focus on decarbonization and a transformation of the steel industry toward eco-friendly production routes (for more on green steel at Primetals Technologies, see "What is Green Steel?" on pages 36–39). As the industry transforms, steel producers are adopting new technologies to change their production routes and move away from fossil fuels. Yet, no single solution can immediately solve the industry's challenges, but the stepwise adoption of innovations will define the new era of green steel.

THE CHALLENGE OF CARBON

Facing the reality of climate change, 153 countries worldwide have pledged their commitment to net-zero carbon emissions following the most recent U.N. Climate Change Conference, COP27, in Sharm el-Sheikh, Egypt. While COP26 in Glasgow, U.K., focused on a commitment to phasing out coal subsidies, reducing methane leakage, and halting and reversing deforestation, the steel industry's immediate impact is reducing energy consumption and moving away from fossil fuels. COP27 achieved progress on a stepwise phase-out of coal and agreed on a global fund to compensate developing companies intensely impacted by climate change, with funding postponed until COP28.

When discussing carbon emissions and their impact on the steel industry, one must look no further than legislation such as the European Green Deal from 2019/2020. The European Green Deal proposes financial mechanisms to help cut greenhouse gas emissions by 55 percent by 2030 compared to levels in 1990 and to reach neutrality by 2050. Similar agencies worldwide will play a decisive role for producers on the road to decarbonization. In 2022, amidst increasing energy prices, Europe also saw an increase in the cost per ton of CO_2 emissions, reaching nearly 100 euros per the Emissions Trading System. With almost two tons of CO_2 produced for every ton of crude steel, the price per ton of CO_2 will play a significant role for steel producers as more countries adopt carbon-pricing schemes—especially with the introduction of the Carbon Border Adjustment Mechanism in Europe as the "free allocation" period is phased out.

While steel producers could reduce carbon emissions by cutting back on production, steel demand is set to rise—especially in India and Southeast Asia, as well »

FIG. 1: E.U. Carbon permit prices (euros per ton of CO_2) per the E.U. Emissions Trading System (2005–2023) demonstrate an ever-increasing trend with sharp increases after 2020.

as in the renewable energy sector and e-mobility. Experts at Primetals Technologies forecast steel demand to reach approximately 2,200 million tons by 2050, which reflects a compound annual growth rate of 0.5 percent. Therefore, the steel industry must find solutions to reduce carbon emissions and meet growing needs.

GROUNDBREAKING SUSTAINABLE SOLUTIONS

While many of the steel industry's challenges seem insurmountable, groundbreaking solutions pave the way toward carbon neutrality. These innovations lead to reduced carbon emissions and improved contributions to the circular economy, and will define a bright future for heavy industries. For the steel industry, the technologies involved include increased electrification, scrap-based production routes, and direct reduction using natural gas and hydrogen. Adjacent infrastructures will also see increased development to meet these needs—e.g., expanding the renewable energy infrastructure and developing a hydrogen and CO_2 eco-system.

Direct reduction plants, electric arc furnaces (EAFs), and endless strip production—i.e., Arvedi ESP—help by immediately reducing carbon emissions, replacing traditional coal-based process steps that emit increased amounts of CO_2, including coke batteries, agglomeration plants, blast furnaces (BF), basic oxygen furnaces (BOFs), and the fossil-fired reheating of slabs for downstream processing. Taking these processes one step further, hybrid mills that operate BFs/BOFs and EAFs will become a major trend for steel producers transitioning stepwise to electric steelmaking. Using a Smelter furnace will define "two-step" steelmaking as we advance. With a variety of immediate solutions and more in development, the shift toward carbon neutrality for the steel industry will occur step by step, and producers are already taking the opportunity to change current production routes for sustained returns.

DIGITALIZATION AND THE SUPPLY CHAIN

Integrating these "green" technologies also requires a close eye on a delicate supply chain. One of the most valuable raw materials for steel producers looking to reduce carbon emissions is scrap. Scrap-recycling is a highly efficient means of reducing the carbon footprint of steelmaking. However, current scrap supplies are limited and insufficient when producing high-grade steels due to contaminants like copper. To that end, SICON and Primetals Technologies have partnered to develop digital scrap-cleaning solutions to create "crafted scrap" (For more on "crafted scrap" at

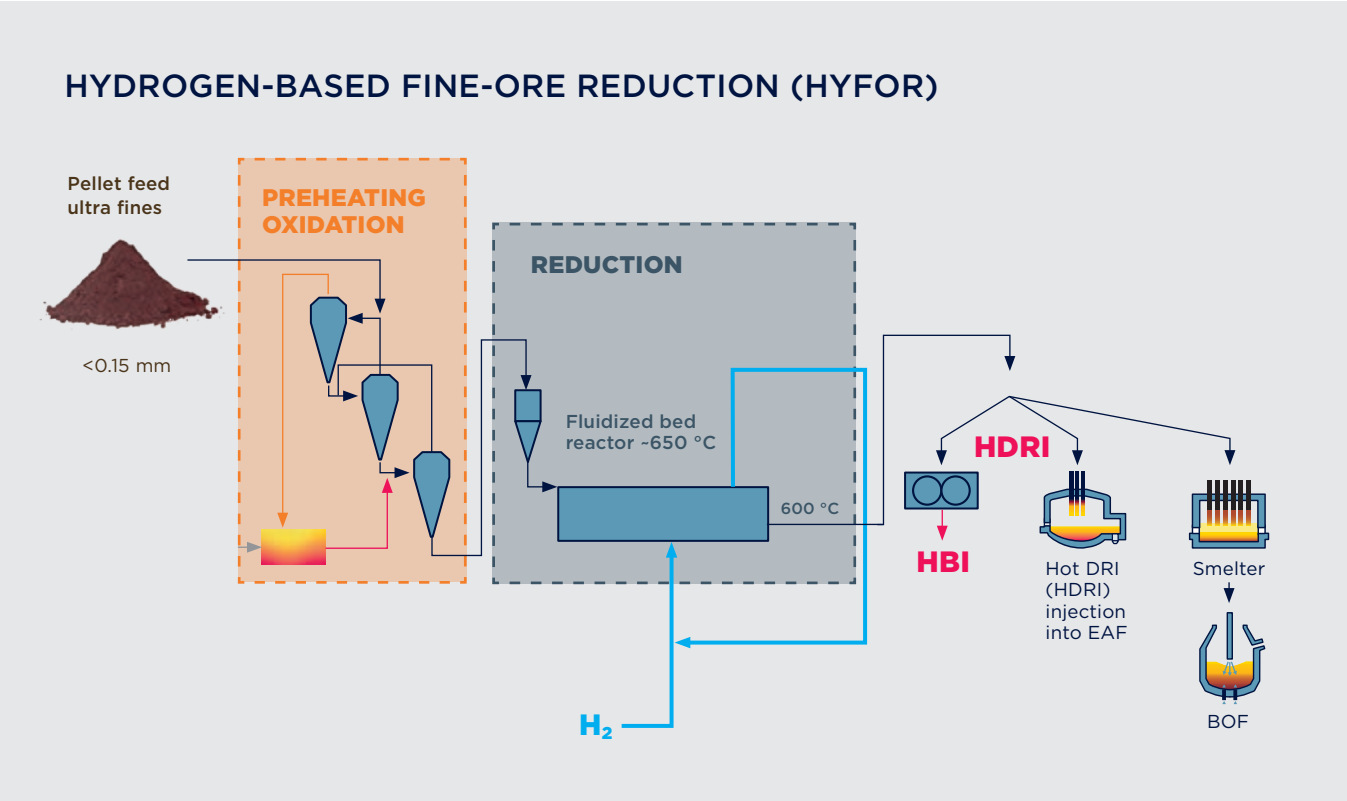


FIG. 2: Depicted above is a flowsheet for Hydrogen-based Fine-Ore Reduction, or HYFOR, an essential technology defining the future of the steel industry.

Primetals Technologies, see "Crafting Quality: Automated Scrap Solutions" on pgs. 54–57). "Crafted scrap" would enable the production of more advanced steel grades based on a higher share of scrap in the charge mix, but even this will not be enough to keep pace with the rising demand for steel. To this end, scrap sorting will become more essential, thanks to the exploding steel-production capacity in the early 2000s, which will return steel to the circular economy with an average lifecycle of 40 years. This trend will support the installation of additional greenfield EAFs to process end-of-life steel and increased scrap use.

THE POWER OF DIRECT REDUCTION

Direct reduced iron (DRI) will play a vital role in the future of steel production and provide the necessary basis to produce advanced steel grades and make up for the demand that scrap cannot supply. The MIDREX direct reduction process using natural gas can reduce carbon emissions by 65 percent when combined with renewable-powered EAFs, compared to the BF/BOF baseline route. Producing DRI or hot-briquetted iron (HBI) based on pelletized high-grade iron ore with natural gas is a transitional solution to reduce CO_2 emissions quickly. However, this problem expands as the amount of low-grade iron ore available worldwide significantly outweighs that of high-grade iron ore. »

WHAT IS THE SMELTER?

As the steel industry uncovers new pathways toward decarbonization, the reduction of iron ore plays a vital role. While hydrogen-based direct reduction shows immense potential, using a Smelter offers steel producers an alternative route for melting and final reduction. The Smelter focuses on melting low-grade DRI, creating an innovative two-step process for steelmaking. The combined first step reduces low-grade DRI and completes final reduction in the Smelter—e.g., a HYFOR and Smelter configuration—, producing green hot metal. After that, metallurgical work is performed in the BOF and secondary metallurgy. A Smelter operates under a reducing atmosphere, well suited for high slag volumes generated from the low-grade DRI. It will generate a slag similar to blast furnace slag, supporting the cement industry's decarbonization efforts as a secondary feedstock. A rectangular Smelter furnace can melt an annual capacity of up to 1.5 million tons of DRI.

Currently in development at Primetals Technologies is the HYFOR process, which focuses on hydrogen-based fine-ore reduction. After going into operation at the voestalpine site in Donawitz, Austria, HYFOR has shown promise to produce net-zero DRI and removes the need for the pelletizing process (see Figure 2). Additionally, through cooperation with POSCO in Korea, HyREX, adapting the FINEX process, utilizes cascading fluidized-bed reactors with sinter feed ores to produce DRI, and later hot metal, using hydrogen in the reduction process and a smelter.

EXPANDING CARBON CAPTURE

While avoiding carbon-intensive processes using new technologies shows excellent promise in several production areas, there will be many hurdles to overcome in the short-, mid-, and long-term for the steel industry regarding carbon emissions. As part of the Mitsubishi Heavy Industries Group (MHI), Primetals Technologies is fortunate enough to access technologies and processes, such as the Kansai Mitsubishi Carbon Dioxide Recovery Process (KM CDR), for carbon capture and storage. Combining the expertise in the metals industry at Primetals Technologies with the unique KM CDR process—already installed at power plants worldwide—may open new doors for off-gas treatment in the steel industry. Together with ArcelorMittal and BHP, Primetals Technologies will investigate the suitability of the process for the steel sector. A pilot plant will be installed to test and optimize the process for the blast furnace top-gas, the waste-gas from reheating furnace, and the flue-gas from direct reduction.

STEPS TOWARD DECARBONIZATION

Companies striving to become industry leaders in green steel production can transform by focusing on "two-step" and "hybrid" steelmaking, combining direct reduction and Smelter technologies or electric steelmaking, or deploying CCS with their current integrated production routes to take the first steps toward decarbonization. The global emphasis on climate change is not only a challenge for the heavy industry but also an opportunity to define a sustainable future for generations. The shape of the future will be determined by strong, sustainable, and recyclable green steel.

Dr. Alexander Fleischanderl, Head of Green Steel,
Primetals Technologies Austria

ETS EXPLAINED

The term "Emissions Trading System" (ETS) has become relatively broad and refers to various mechanisms to accelerate and incentivize the adoption of low-carbon technologies. Firstly, an ETS is not the same as a carbon tax, which places a direct tax on emissions. An ETS uses a fluctuating carbon price, like market-based trading. The E.U.'s ETS uses a "cap-and-trade" system, meaning a "cap" is set on specific emissions by groups who can purchase and trade emissions allowances.
By lowering the cap each year, emitters are forced to trade allowances, which fluctuate based on the market, or invest in technologies to reduce their overall carbon emissions. Introducing policies such as the Carbon Border Adjustment Mechanism (CBAM) in Europe also adds another element of carbon pricing on imported and exported carbon emissions.

meta.ls/greensteel

VDMA TECHTALK:

BREAKTHROUGH SOLUTIONS FOR GREEN STEEL

While there are major considerations on the path to green steel, the recognition of these roadblocks as areas for improvement and innovation is at the heart of the Green Steel task force at Primetals Technologies. Scan the QR code to learn more.

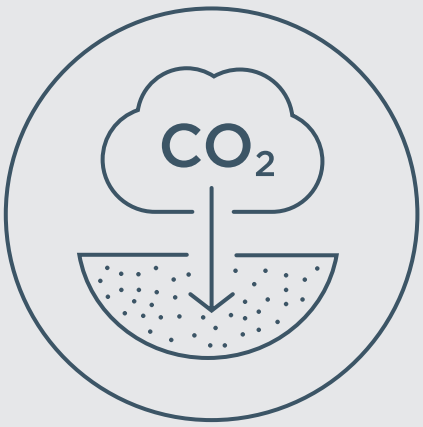
THE THREE PATHS TO **GREEN STEEL**

ELECTRIFICATION OF PRODUCTION

Increasing demand for steel in the coming decades necessitates expanding clean, renewable energy to enable sustainable production processes. First, to feed a growing number of electric furnaces, and second, to produce the green hydrogen required to replace carbon-based reductants. Additionally, renewable energy, such as solar and wind energy, needs more steel per energy-unit built than most fossil fuel-powered plants, fueling the demand for steel.

CARBON DIRECT AVOIDANCE (CDA)

The principal reduction of iron ore is limited to three pathways: carbon-based reduction, a common practice to date; hydrogen-based reduction, the near future; and direct electrolysis of steel, still in its infancy. The only realistic scenario today remains to establish a hydrogen economy. But large-scale hydrogen production has yet to be realized, and renewables are still scarce. A mid-term green hydrogen price of less than $2 per kilogram suggests these roadblocks will diminish sooner than later.



CARBON CAPTURE & STORAGE (CCS)

Asset lifetime in the steel sector exceeds 40 years, and many upstream ironmaking facilities in India, China, or other regions are still very young. Here, carbon capture and storage (CCS) comes into play. CCS relies on state-of-the-art processes like Mitsubishi Heavy Industry's KM CDR amine scrubber-based capturing system. After capture, the concentrated and pure CO_2 can be compressed and safely stored underground. Alternatively, it can enhance oil recovery or produce base chemical products. For example, LanzaTech's proprietary microbial fermentation process ferments CO_2, CO, and hydrogen into ethanol—i.e., eFuels—or other base chemicals.

WHAT IS GREEN STEEL?

DEFINING THE FUTURE OF THE STEEL INDUSTRY

Amidst growing demands for eco-friendly production routes and persistent actions for a more sustainable future, a new term in the steel industry has emerged: "green steel." While the terminology may differ—from net-zero to low-carbon steel—green steel encompasses an array of sustainable topics, from electrification and hydrogen eco-systems and direct reduction to the circular economy and carbon capture, utilization, and storage. This article examines the state of the steel industry and the term "green steel" as both a trend toward sustainability in steel production and a low-carbon end product.

From carbon lean to net-zero, it seems all but clear that the preoccupation of the steel industry with decarbonization is more than a short-term fad. Above all, this represents a positive trend for the steel sector regarding its environmental impact. Worldwide producers are making their stance on the environment known by creating a new line of products under the banner of "green steel" and adapting their production routes to meet stringent environmental regulations, effectively "greening" their entire production chain. One thing is clear, green steel is here to stay. But what is green steel exactly?

MEETING GROWING DEMANDS

Perhaps the most telling feature of green steel has been a focus on carbon emissions. Decarbonization in the steel industry has gained much attention for various reasons. Currently, the steel industry contributes to approximately eight percent of global CO_2 emissions. Decarbonization is key to a sustainable future for the heavy industry. With 1,951 million tons of crude steel produced in 2021 at nearly 1.85 tons of CO_2 per ton of crude steel, signs point to the vast potential for improvement regarding decarbonization. Additionally, with the demand for steel increasing, including in sustainable energy sectors, such as wind and solar power, producers must find a way to meet market demands while reducing their environmental impact. Beyond meeting rapidly growing market demands, producers also must factor in various strategies regarding emergent policies for environmental regulations, which are not always straightforward or sustainable. Currently, producers must remain flexible and conscious of these changes until a clear strategy emerges.

Governments and organizations are implementing measures to make improving the environmental impact of steel production both essential and attractive. Among these strategies are emission trading systems designed to ensure that steel producers pay for the CO_2 they emit. Producers will have to account for their direct emissions (Scope 1) using the definition of "scope emissions." They may also have to account for the amount of CO_2 generated indirectly via energy purchase (Scope 2) or indirect value chain emissions for upstream and downstream activities (Scope 3) from the purchase of raw materials to logistics and transport. In Cremona and Triest, Italy, Acciaieria Arvedi became the first certified net-zero CO_2 emissions steel mill for Scope 1 and Scope 2 emissions. By decreasing the amount of CO_2 emissions early on, producers avoid unnecessary costs as their capacity increases. The demand placed on the steel industry to lower CO_2 emissions is apparent for the future, but this is only one aspect of green steel and the industry's sustainable future.

CREATING A SUSTAINABLE FUTURE

Due to its ease of calculability, carbon emissions have remained a focus for environmental groups and governments worldwide, but this is only one aspect of sustainability. In 2015, the U.N. established a set of targets known as the Sustainable Development Goals as part of the 2030 Agenda for Sustainable Development. The plan is a culmination of initiatives from the U.N. to improve sustainability worldwide. These initiatives focus on all pillars of sustainability, including the social, environmental, and economic factors that contribute to lessening inequality and enhancing prosperity. For the steel industry, this also means adopting technologies and practices that broadly protect the environment and contribute to sustainable goals.

As previously mentioned, green steel has primarily been the focus of decarbonization efforts in the steel industry. However, it stands to reason that "greening" production extends well beyond decarbonization and involves improved technologies that benefit the circular economy, the reduction of various other pollutants, improved energy consumption, resource efficiency and water usage, and the protection of human rights. Thus, sustainable steel production, a "green" steel production, is based on fundamental sustainability principles. While all these aspects of "green" production appear clear, where does green steel as a product fit into sustainability?

WHAT IS GREEN STEEL?

The steel industry is not alone in its pursuit of sustainability and decarbonization. Parts of the U.N. Sustainable Development Goals extend to technology, »

RESPONSIBLE STEEL

Without a globally recognized industry standard for sustainable steel and green steel, several organizations have emerged to help the industry define and reduce its environmental impact. One example is the nonprofit organization ReponsibleSteel. Recognizing a need for standardization across the globe, from mining operations to deliverable products in the steel industry, ResponsibleSteel aims to ensure consumers that their steel has been responsibly sourced and produced. Their certification involves a series of audits provided by third-party organizations to avoid bias, which are then verified by ResponsibleSteel. The results of their certificates are kept transparent to establish trust in their organization and its ability to verify a sustainable and responsible site. In April of 2022, ResponsibleSteel awarded its first certification in North America to Big River Steel in Osceola, Arkansas, U.S.A.

THE THREE PILLARS OF **SUSTAINABILITY**

SOCIAL

The social aspect of sustainability encompasses the human element of society and how it interacts with the environment and the economy. From forming and preserving communities to advocating for equality and human rights, sustainability impacts the social dimension of our society in that we satisfy basic human needs for all persons across the globe.

ECONOMIC

Much of the discourse around sustainability pays particular attention to the human element—for instance, diversity and human rights—or the ecological, e.g., environmental regulations. However, economic development is also a crucial aspect of sustainability. In terms of sustainability, the economy is not merely about sustaining growth but striking a balance between financial motivations and the other two pillars. In the past, more attention has been paid to economic growth, while human suffering and environmental destruction have remained.

ENVIRONMENTAL

Often written as ecological, environmental sustainability is perhaps the most well-known aspect of sustainability and plays a crucial role in everyday reference to sustainability practices. The environment is vital to supporting social and economic sustainability. In both economic and social contexts, an environment that contributes to the health of society is well-protected and sustainably managed. A healthy environment provides the conditions to meet all our needs for generations.

Green steel production encompasses various aspects of eco-friendly production, from water and off-gas treatment to decarbonization and improved energy efficiency.

infrastructure, and energy productivity improvements, which closely involve the steel industry. Steel producers are catering their products to contribute to a "greener" world. One area of interest for green steel producers is e-mobility and the automotive industry.

As electric vehicles become more and more prevalent and standard vehicles seek to decrease their mass, the demand for lighter, stronger steels will also increase. (For more on the green future of e-mobility and the rolling technologies capable of producing electrical steel grades, see "Meeting Demand: Electrical Steel and Mobility" on pages 72–77) Electric vehicles demand particular steel grades known as "electrical steels" and increase the amount of silicon steel found in cars. The market demand for this type of steel is expected to grow in the coming years as individual mobility strategies shift away from fossil fuels.

Beyond green steel as a base material for the automotive industry, "low-carbon" steel and greener steel production will benefit from the increased demand for steel to strengthen public transit and energy infrastructures for a more sustainable future. As green steel is both a significant addition to steel producers' portfolios and a positive part of a transition toward a more sustainable future for the steel industry and society, what is Primetals Technologies contributing to this development?

GREEN STEEL AT PRIMETALS TECHNOLOGIES

In May 2022, Primetals Technologies launched a new organization called "Green Steel." The initiative seeks to identify synergies between parts of the portfolio of Primetals Technologies and incorporate technologies from Mitsubishi Heavy Industries. What's most important to the approach to green steel at Primetals Technologies is the ability to adapt to the various demands and requirements of steel producers worldwide. Currently, there is no internationally recognized standard for green steel production. However, governmental initiatives to regulate steel production to make it more environmentally friendly are emerging around the globe.

For green steel production, Primetals Technologies can adapt to meet varying standards and address all aspects of eco-friendly production, including water treatment, off-gas treatment, CO_2 reduction, and more. Additionally, solutions covering all aspects of the production chain can be revamped to produce premium products that may then be labeled "green steel." Concerning digitally enhanced decarbonization, a vast array of automation and digitalization packages contribute to sustainable goals, including safety. These solutions support green steel production by optimizing processes, reducing waste, and increasing energy efficiency.

As the transition toward a more environmentally friendly production route for the steel industry continues, it will require cooperation beyond geographic and industrial borders. Being a company with a broad portfolio to enhance steel production and locations across the globe, Primetals Technologies is proud to be a part of the industry transition toward green steel. Alongside the "Mission Net Zero" initiative of Mitsubishi Heavy Industries Group, which targets carbon neutrality by 2040, Primetals Technologies is poised to help industry leaders realize their own goals as they transition to green steel production and pioneer a more sustainable future for the steel industry. |

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Arvedi Group

TWO HEARTS BEATING FOR STEEL

AN INTERVIEW WITH GIOVANNI ARVEDI, THE ENTREPRENEUR AND INNOVATOR WHO CONCEIVED TRUE ENDLESS STRIP PRODUCTION, AND MARIO ARVEDI CALDONAZZO, CEO OF ARVEDI GROUP

What does it take to innovate in the steel industry? And how do you take the steps required to turn inspiration into a successful business model? In this interview, we immerse ourselves in the world of Arvedi Group—the company that pioneered endless strip production—and we discover what's possible when dedication, realism, and ingenuity come together.

> **“To innovate means taking risks, which need to be calculated and carefully measured.”**
>
> Giovanni Arvedi
> Founder and President, Arvedi Group

What inspires you to be an innovator in the steel industry?
Giovanni Arvedi: I like to say that the drive for innovation is like a being that takes root and grows within us until it envelops us totally—and at this point, we must then give life to the project. “Innovation” is a word behind which hides in-depth study and sacrifice, and it cannot be faced without humility and respect for nature and physical laws. To innovate means taking risks, which need to be calculated and carefully measured. Specifically, regarding the steel sector, I was inspired by my critical assessment of the conventional production cycle and its limits—such as capacity and production costs—particularly for thin gauges and specialized steels.

Is there a strong personal connection between your life in general and your inventions?
Giovanni Arvedi: I have always kept in mind that history’s greatest innovator, Leonardo da Vinci, was first and foremost a great observer of nature, and it was this attitude that inspired his brilliant inventions. I feel very close to nature—for which I have great respect, above all as a Christian and an entrepreneur—and I think this has undoubtedly helped me make important technological decisions. I am not a man of science and seek inspiration on a spiritual level, as well as through dialog, exchange, and confrontation with others. The strength and courage to implement my ideas derives from this and, of course, I have the benefit of essential technical support.

When and how did you first come up with the idea of Arvedi ESP? »

CAVALIERE GIOVANNI ARVEDI

Giovanni Arvedi, who holds the “Cavaliere” title—the Italian equivalent for the British “Sir”—is one of the metals industry's few living legends. He first conceived the idea of endless strip production in the 1980s. What began as an inspired concept eventually became a reality—thanks to Arvedi's ingenuity and perseverance and with the support of Primetals Technologies. Today, it is even clearer how revolutionary endless strip production was at the time. Arvedi ESP is now regarded the greenest way to cast and roll “direct application” quality strip as thin as 0.8 millimeters.

Giovanni Arvedi: It began in the 1980s when procurement problems for my tube manufacturing operations brought me into contact with the limits of conventional casting and rolling production.

How has Arvedi ESP developed since then?
Giovanni Arvedi: In the early 1980s, continuous casting was still evolving, but awareness of the capabilities of endless strip production was rising. This evolution led to the extension of the production process toward a truly continuous one, Arvedi ESP, which 15 years earlier was a clear concept but not yet achievable in concrete terms.

What did it feel like to produce the first coil using your own custom-designed technology?
Giovanni Arvedi: It was certainly hugely satisfying, and since producing the first coil, we have done an incredible amount of work to continually improve casting performance.

What sets Arvedi ESP apart from other solutions on the market?
Giovanni Arvedi: Real-world results show that Arvedi ESP is the most compact process, improves product quality, and reduces operational and investment costs. It is the only technology that can reach large production volumes of ultra-thin steel gauges with better tolerances than cold-rolled products. It is flexible in terms of size and can adapt to the production demands of steel manufacturers in terms of the range of steel grades, gauges, and widths.

Is there any aspect of Arvedi ESP that you are particularly proud of?
Giovanni Arvedi: Arvedi ESP is a net-zero-emissions production solution in terms of CO_2, which makes it truly unique. ESP is an answer to the great question of global climate change.

How "green" is Arvedi ESP today and can it become more environmentally friendly?
Giovanni Arvedi: In 2022, Acciaieria Arvedi was the world's first steelworks to achieve net-zero certification. This was thanks—above all—to Arvedi ESP technology and to decisions made some 30 years ago when we were the only ones in Europe to choose the electric furnace for the melting process in the production of flat steels. Moreover, ESP is a process that reduces energy consumption by 50 percent, and there is still potential for further improvement in the future.

Do you generally develop new solutions with future generations in mind?
Giovanni Arvedi: Arvedi ESP is a state-of-the-art technology. However, I believe there are further improvements to be introduced. We are developing these with Primetals Technologies and experimenting in Cremona on the existing line, the master plant, which is constantly being updated. The new process certainly has benefits that will help future generations. We are also working on a new idea, the patent for which is on its way, that will introduce interesting elements of flexibility.

> **"If we exchange a euro, in the end, we are each left with a coin. But if we exchange an idea, we both end up with two ideas and are truly richer for it."**
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> Giovanni Arvedi
> Founder and President, Arvedi Group

Beyond metals production, is there any technology that fascinates you?
Giovanni Arvedi: Clean exploitation of nuclear energy, which is still under development and hasn't yet found a balanced solution in terms of energy yield, environmental risks, and investment costs. I also follow with interest all the technologies that can be introduced to tackle climate change, including those in agriculture—which is a family activity that I undertake passionately in my spare time.

If you could give your younger self one important piece of advice, what would it be?
Giovanni Arvedi: To face life's challenges with courage, competence, and humility. To listen and engage with others. I like to tell my fellow workers that if we exchange a euro, in the end, we are each left with a coin. But if we exchange an idea, we both end up with two ideas and are truly richer for it.

What are your hopes for Arvedi ESP in the future?
Giovanni Arvedi: To see it spread as a process that improves both steel production itself and the environmental footprint of our sector. »

FIG. 1: A bird's eye view of Acciaieria Arvedi's main production site in Cremona, Italy.

FIG. 2: The "master plant" is still the basis for further refinements of the Arvedi ESP technology.

FIG. 3: The Cremona plant features one of the nicest-looking control pulpits in the industry.

FIG. 4: This ESP-made strip is 0.8 millimeters thin and of a quality comparable to cold-rolled material.

FIG. 5: After leaving the downcoiler, the newly made product is quickly whisked away.

MARIO ARVEDI CALDONAZZO

After more than 20 years working at his uncle Giovanni Arvedi's company, Mario Arvedi Caldonazzo assumed the role of CEO of Arvedi Group only recently. While he is committed to maintaining the existing set of values and ambitions, Caldonazzo also has a number of dedicated focus areas. He aims to align every aspect of the company with the principles of the circular economy. While Arvedi Group already employs many younger workers, Caldonazzo thinks that even more attention to future generations is possible. And he wants to implement even more digital solutions.

What makes Arvedi unique in the steel industry?
Mario Arvedi Caldonazzo: I think the uniqueness of our company comes from the unparalleled personality of its founder and chairman, Giovanni Arvedi. Through his strategic vision, starting from a greenfield site, he has created a solid, articulated, and integrated industrial group comprising a "carbon steels" business unit—Acciaieria Arvedi and its subsidiaries—, a "stainless steels" unit—Acciai Speciali Terni—, and the companies, tube mills, re-rolling, and service centers connected to them. Each company is unique from an industrial and organizational point of view. Take, for example, Acciaieria Arvedi, the only European electric arc furnace-based and fully integrated flat steel producer: it covers all production steps from scrap handling to cutting the strip on the same production site.

Is there anything particular about Italian entrepreneurship?
Mario Arvedi Caldonazzo: Italians, once a "people of saints, poets, and navigators," have become a people of entrepreneurs. It is our individualism that distinguishes us, and this is reflected in the constant creation of companies, often micro-companies, the main feature of which is outstanding vitality. Italian entrepreneurship is without equal in the world and the real backbone of our country, characterized by creativity and flexibility. It works well in some sectors, mainly the transformational ones, and less in others, where size and governance have an important role. I am often amazed at how Italy manages to be the world's seventh industrial power without raw materials and energy. The reason for this is our common entrepreneurial spirit.

Which markets are you currently targeting?
Mario Arvedi Caldonazzo: Our group's industrial footprint is markedly Italian, but our scope is global. We export over 60 percent of production, mainly to Europe, serving hundreds of customers with the most sophisticated products. Our strength is in diversification—in the sense that we do not depend on a key sector but are present everywhere, from the construction industry to aerospace.

How is Arvedi Group contributing to the Cremona region economically and socially?
Mario Arvedi Caldonazzo: Arvedi Group represents an important part of the GDP of the province of Cremona and is a highly relevant employer. We recognize ourselves in and love the local community, which we try to support through the "Fondazione Giovanni Arvedi e Luciana Buschini." Over the course of its 30 years of activity and with input from Giovanni Arvedi, the foundation has realized wonderful projects in Cremona, from the Violin Museum [see the box to the right, ed.] to the campus of the Università Cattolica and the soon-to-be-completed campus of Politecnico di Milano. "30 years lived in joy," my uncle Giovanni likes to say, recalling everything he has done for our town thanks to the work of all our employees.

What are the challenges and opportunities of today's steel business?
Mario Arvedi Caldonazzo: We are currently experiencing some of the hardest times in our history—in the sense that we are being subjected to frightening increases in the cost of materials and energy, against a very rigid market, massively penetrated by imports from countries that have not suffered the energy shock, are often subsidized, and pay little attention to the environment and social rights. Our group has shown resilience thanks to enormous efforts and investments in technological innovation. The challenges and opportunities are a consequence of climate change. Despite the increase in costs, we also have an opportunity to establish ourselves on the market with green steel. Customer sensitivity to this is growing, and, in July 2022,

> **“Arvedi steel, besides being a net-zero-emissions product, is also zero-waste and fully circular—a global benchmark of sustainability.”**
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> Mario Arvedi Caldonazzo
> Chief Executive Officer,
> Arvedi Group

Acciaieria Arvedi became the world’s first steelworks to achieve net-zero certification. The new steel will be launched onto the market in November and we believe that the investments made to achieve this extraordinary goal will soon be repaid. Arvedi steel, besides being a net-zero-emissions product, is also zero-waste and fully circular—a global benchmark of sustainability. The same experience and know-how will soon be transferred to Acciai Speciali Terni so that we can swiftly reach complete decarbonization of the production site.

What does the future of Arvedi Group look like?
Mario Arvedi Caldonazzo: We have achieved a solid financial position and have consolidated satisfactory profitability. We will continue to grow, replicating and developing our model of technological innovation and sustainability.

What interests you personally, aside from metals production and business-related fields?
Mario Arvedi Caldonazzo: Like my uncle Giovanni's, my life is devoted to the family company within which I have found everything: stimulation, passion, interests, and social relations. Through the foundation, I involve myself in culture, mainly music and art. My spare time is dedicated to my wife and children. |

CHARITABLE INITIATIVES

Giovanni Arvedi's family came to the Cremona region from Trentino in the 1700s and has built close ties with the local community. Together with his wife, Luciana Buschini, Arvedi has realized a number of charitable projects, many of which are geared toward supporting the younger generations. The Stradivari Violin Museum (pictured) is particularly remarkable.

THE NEW AGE OF **HBI**

AS THE GLOBAL FOCUS ON DECARBONIZATION GROWS, THE STEEL INDUSTRY LOOKS TO HOT-BRIQUETTED IRON AS A LOW-CARBON ALTERNATIVE TO TRADITIONAL IRONMAKING.

Primetals Technologies provides answers to steel producers who ask, how should I incorporate direct-reduction based ironmaking into my medium and long-term strategies?

Hot-briquetted iron—with its lower carbon footprint—contributes to the decarbonization of steel production.

As the world trends toward carbon neutrality, hot-briquetted iron provides answers to a seemingly impossible challenge.

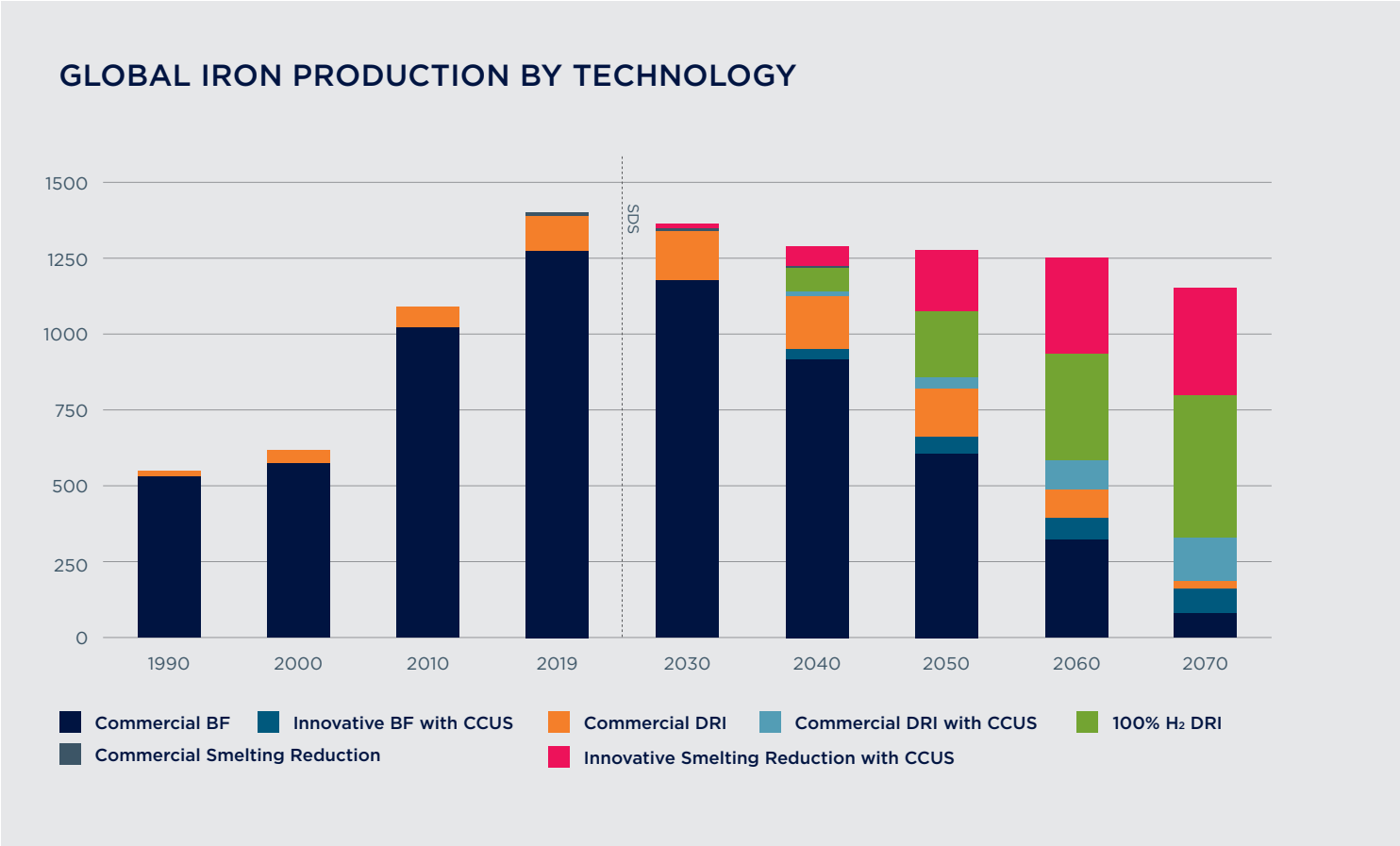


FIG. 1: Global iron production by technology in the "sustainable-development scenario" (SDS) from 2020 onward according to the International Energy Agency (BF: blast furnace; CCUS: carbon capture, utilization, and storage; DRI: direct reduced iron)

As the reality of carbon neutrality as a global trend unfolds and pressures of net-zero carbon initiatives increase, it is evident that, despite these developments, the global economy cannot do without the versatile material of steel. In 2020's "Iron and Steel Technology Roadmap," the International Energy Agency (IEA) projected global steel demand to rise by 10 percent by 2050, noting how deeply engrained steel is in our society, from construction to infrastructure and transportation. The report also pointed out that many technologies of a net-zero energy transition rely heavily on steel, such as wind turbines, solar panels, as well as carbon capture and storage technologies.

Given this projected increase in demand, coupled with rising pressure to reduce carbon emissions, the industry is searching for efficient, adaptable, low-carbon solutions on their path to net-zero emissions by 2050. As these projections confront the status quo of the iron and steel industry, several aspects of future-proof strategies emerge:

- decrease in integrated steel production (using the blast furnace and basic oxygen furnace)
- increase in electric steelmaking (using the electric arc furnace)
- increase in scrap usage
- increased use of direct reduction, producing direct reduced iron (DRI), and especially hot-briquetted iron (HBI)

LOW-CARBON INNOVATIONS

As the steel industry moves toward carbon neutrality in response to increasing pressures to decarbonize, the application of DRI and HBI will see immediate benefits for steel producers. HBI is an exceptionally flexible product as well. Taking the place of traditional pig iron for primary steel production, HBI can also supplement lower-grade scrap, enabling higher-grade steel products. The supplement of HBI for lower-grade scrap dilutes the metallic impurities often found in scrap-based steelmaking and can even allow, for example, for the production of flat products, which have been an exclusive product offered by the integrated steel production route using virgin materials.

Yet, HBI has also made a name for itself beyond its ability to reduce carbon emissions and its versatile applica-

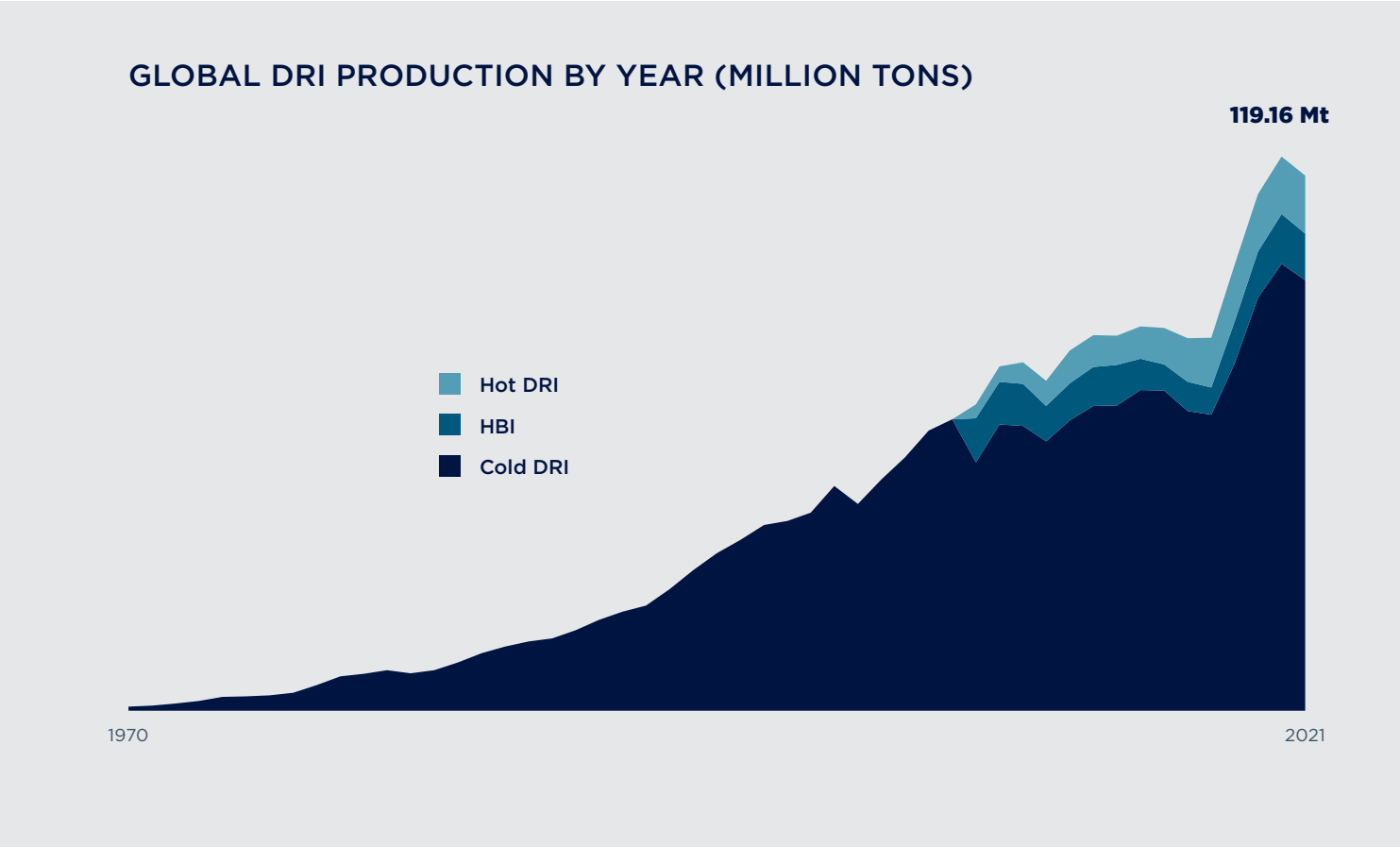


FIG. 2: DRI production from 1970 to 2021 from the 2021 "World Direct Reduction Statistics" compiled by Midrex Technologies (DRI: direct reduced iron; HBI: hot-briquetted iron)

tions, namely in its ability to be shipped far and wide. For HBI, re-oxidation is not an issue. This means that regions rich in raw materials with low energy costs can readily produce HBI and ship this valuable material to steelmaking facilities worldwide. However, countries have begun establishing barriers to compensate for carbon emissions through carbon prices on selected imports, such as the E.U.'s "Carbon Border Adjustment Mechanism" to tackle climate change. Thankfully, since natural gas based HBI has a significantly lower carbon footprint than traditional blast furnace based hot metal, these new trade regulations should not impact HBI as a global commodity. Moreover, carbon pricing schemes coupled with carbon border taxes will only make merchant DRI more competitive worldwide.

The global growth of annual DRI output already reflects the future competitiveness and impact of these developments. In 2019, DRI production hit a record 108.1 million tons—7.3 percent more than the previous year, owing most of its increase to India, Iran, and Algeria. In 2021, DRI production reached 119.2 million tons, up by 10.2 percent from 2019. While growing output in India—the world leader in DRI production— »

Access to natural gas and iron-ore deposits is vital for developing new direct-reduction capacities. But access to energy for clean hydrogen production will become even more relevant in the future.

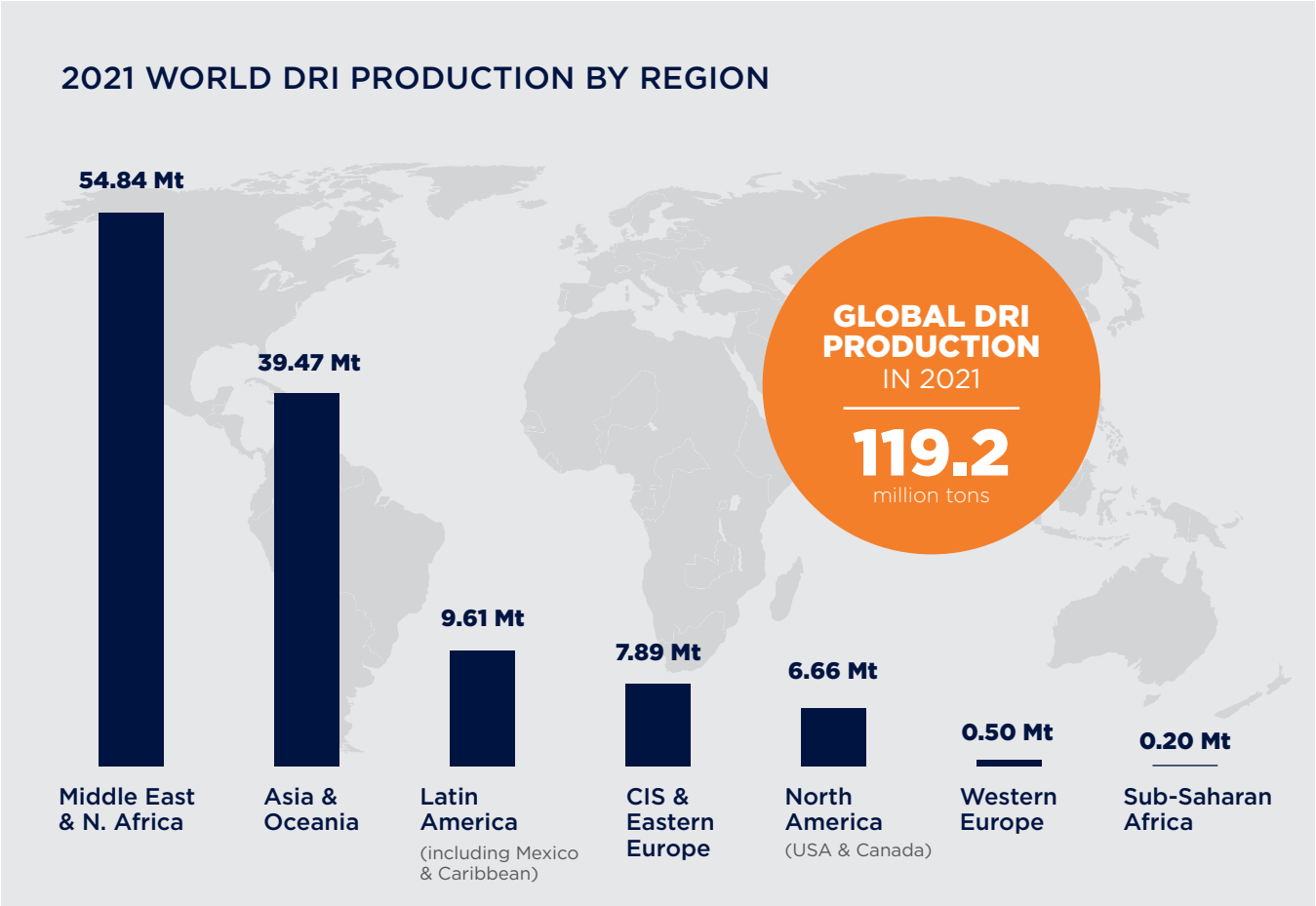


FIG. 3: Courtesy of Midrex Technologies' 2021 "World Direct Reduction Statistics," this map shows the global DRI production based on region.

was due to productivity growth in coal-based rotary kilns, the gains posted by Iran and Algeria all came from the newly installed capacities of natural gas-based MIDREX plants. In Algeria specifically, DRI production bounced back in 2021, with Tosyali Algerie setting a record for DRI production at 2.28 million tons. According to estimates in its "sustainable development scenario," the International Energy Agency (IEA) projects the market for commercial DRI to continue its growth from 115 million tons per year in 2019 to 157.3 million by 2030. At the same time, the IEA expects that gas-based DRI will account for 8 percent of steel production by 2030 (see Figure 1).

REGIONS WITH GREAT POTENTIAL

To fully harness the potential of DRI, it will take production increases that only an entire fleet of new HBI plants can handle. New HBI plants must be situated in areas with access to iron ore and natural gas, or hydrogen. Regions such as Canada, Sweden, and Western Australia, with vast ore deposits and a high potential for renewable energy, seem to be exceptionally well-placed in this regard. The regions' policymakers and industry leaders have also identified this potential and acted accordingly. Primetals Technologies has also recognized this potential, and joined the Heavy Industry Low-Carbon Transition Cooperative Research Centre, established by the Australian Government, to explore the tremendous opportunities in this field.

Meanwhile, the U.S.A. and China are two countries that stand out for different reasons in the race toward carbon neutrality and HBI capacities. These countries have significant EAF steelmaking capabilities but little HBI capacity. Although there are now two HBI plants in the U.S.A., China has no HBI plants, despite investing heavily in its EAF capacity over the last few years. Additionally, China has announced a 2060 net-zero target. As the largest steel producer globally, China will not meet its goal by solely relying on scrap, which is already in short supply. Instead, investment and expansion in electric steelmaking require an increase in merchant HBI.

Some steel producers in regions with high energy costs, such as Europe, are increasingly looking for new

FURTHER READING

Read more about the involvement of Primetals Technologies in developing the HBI plant in Corpus Christi, Texas, U.S.A., in "DRI Plants, Tailored to Your Needs" from Metals Magazine 2019.

meta.ls/DRI

FIG. 4: VP of Direct Reduction Wolfgang Sterrer on site at one of the plants designed by Primetals Technologies ensuring proper implementation and execution

solutions. For example, in 2016, Austrian steel producer voestalpine began operating an HBI plant near Corpus Christi, Texas, to import the HBI back to Austria. By signing off-take agreements with HBI producers or even building their own HBI plants in areas with lower energy prices and transporting the HBI for use in their domestic operations, these producers have found solutions to meet current demands. Despite some promising increases in HBI production in 2021, including Cleveland-Cliffs' HBI plant in Toledo, Ohio, the demand for HBI will undoubtedly multiply over the coming decades. Thus, current production capacities will struggle to meet the growing demand.

THE HBI PLANT: H_2-READY

While global growth in the area of HBI production is undoubtably on the horizon, producers looking to increase capacity run the risk of increasing their carbon emissions. However, as renewable technologies expand in adoption worldwide, and alternative energy sources contribute to a expanding hydrogen economy, HBI has one key advantage, namely, the possibility for future hydrogen-based production.

According to the IEA's projections, fully hydrogen-based DRI will account for 3.9 million tons of global production by 2030, and 212.6 million tons by 2050. Based on these projections, hydrogen-based DRI and Smelter reduction coupled with carbon capture and storage will continue to grow until they dominate ironmaking by the 2070s. The IEA's projections are not just theoretical dreams but reflect an international trend toward low-CO_2 HBI and DRI systems that are hydrogen-ready today.

As carbon pricing and other regulatory measures impact ironmaking, the reality of competitive hydrogen-based production on the global marketplace may be closer than we assume. Still, access to (or at least a long-term perspective for) low-carbon or green hydrogen from renewable energy will be decisive for industry leaders.

While carbon neutrality and hydrogen technologies become more than mere talking points, some analysts now expect the price of hydrogen to drop much sooner than anticipated. Additionally, increased production capacities for green hydrogen from electrolysis— »

FIG. 5: A close-up view of the MIDREX HBI plant in Corpus Christi, Texas, U.S.A.

MIDREX HBI PLANT: CORPUS CHRISTI, TEXAS, U.S.A.

Annual capacity:	2 million tons
Input material:	100% DR grade pellets
Furnace type:	MIDREX MEGAMOD
Inner diameter of reduction furnace:	7.15 meters
Number of reformer bays:	20-bay reformer with 600 MA-1 reformer tubes (250 millimeters)
HBI metallization:	93%
Carbon content:	1.5%
Other plant features:	• Environmentally friendly burners for NO_x reduction • Flue-gas hot fan to reduce electric power consumption • Hot-fines recycling system • Level 1 and Level 2 automation, including the DRIpax DR Optimizer

With ironmaking technologies that anticipate carbon neutrality, Midrex Technologies and Primetals Technologies are paving the way for the new age of HBI.

using electricity to obtain hydrogen from water with renewable energy—and turquoise hydrogen from pyrolysis—using natural gas to yield both hydrogen and black carbon and producing fewer carbon emissions—will drive down the cost of hydrogen-based production.

GREEN METALLURGY AND THE FUTURE

With an eye toward the future, Midrex Technologies and Primetals Technologies can produce high-quality HBI with the most environmentally friendly technology for ore-based ironmaking. The natural gas based MIDREX direct reduction process releases 50 percent fewer carbon emissions than blast furnace ironmaking. Combine this technology with green hydrogen, and there is potential to decrease carbon emissions even further.

With a proven history in HBI plant construction, Midrex Technologies and Primetals Technologies have successfully implemented plants worldwide to meet the increased demand for merchant HBI. With a reputation for future-oriented innovation, the newest plants can be adapted to use hydrogen as a reducing agent in any range up to 100 percent, once this green energy source becomes economically viable.

With the development of renewable energy infrastructures, combined with ironmaking technologies that anticipate low-carbon and carbon-neutral iron and steel production, Midrex Technologies and Primetals Technologies are paving the way for the new age of HBI.

Johannes Rothberger, Head of Sales, Direct Reduction
Robert Millner, Head of Technology, Direct Reduction
Wolfgang Sterrer, Vice President, Direct Reduction
Adam Merki, Lead Editor
(All with Primetals Technologies Austria)

TECHNOLOGY THAT EXCITES **DIRECT-REDUCED IRON**

VP of Direct Reduction at Primetals Technologies Wolfgang Sterrer shares his excitement for DRI and H_2-ready technologies.

What makes direct reduction fascinating?
Wolfgang Sterrer: Direct reduction is a unique technology thanks to its ability to use natural gas and hydrogen as a reducing agent, unlike other processes. By implementing direct reduction, iron and steel producers are able to reduce CO_2 emissions significantly.

What makes the global transformation of the iron and steel industry so exciting?
Sterrer: In my view, the current transformation is unparalleled because it represents a global approach and a multi-national cooperation of various stakeholders toward the goal of reducing CO_2 emissions. As metal producers explore new frontiers by adopting new technologies, the viability and consideration of new regions—including those rich in natural gas, or areas primed to produce green hydrogen—will create new opportunities for partnerships and frontrunners in the industry.

What makes H_2-ready technologies so essential to the iron and steel industry?
Sterrer: Using hydrogen and green electricity as primary energy sources is the steel industry's ultimate goal. Natural-gas based direct reduction, which is H_2-ready, responds to the challenges that steel producers face today. For the future of the metals industry, Primetals Technologies offers and develops technologies that can considerably reduce CO_2 emissions throughout the iron and steel production chain.

CRAFTING QUALITY AUTOMATED SCRAP SOLUTIONS

"CRAFTED SCRAP" IS REDEFINING SCRAP-BASED STEELMAKING

Increased use of scrap is only as valuable to steel producers as the quality of the scrap itself. To reliably produce high-grade steel, scrap must be processed, cleaned, and sorted. Recognizing the value of scrap for producers in decarbonization efforts and seeing room for improvement, Primetals Technologies sets a new standard for scrap quality with "crafted scrap."

Crafted scrap is the future of scrap-based steelmaking and will transform how steel producers manage and maintain scrap yards.

FIG. 1: A view of the EcoScan online sorting and analyzing scrap

Along with electric steelmaking, scrap use has become a growing trend in the steel industry. While always making up a part of steelmaking, until now, scrap rates have been limited. However, with the ability to process charges of 100 percent scrap, electric arc furnaces are placing additional pressure on an already limited scrap market. Yet, for electric steelmaking, scrap presents a series of challenges regarding yield and quality. Today, scrap use generally comes with several challenges, but "crafted scrap" is ready to change the world of scrap-based steelmaking.

THE CHALLENGES OF SCRAP

If one were to ask steel producers today to reliably report on the number of contaminants, residual materials, and metals in their scrap, the answer would vary greatly. Today, scrap represents a valuable but often unreliable input material for melting units in steelmaking. Based on small sample tests or visual checks, steel producers rely on scrap suppliers and experienced operators to identify and categorize their scrap at the scrap yard. Additionally, there are no internationally agreed upon regulations regarding the number of contaminants in scrap and regulations can vary dramatically between suppliers. Thus, producers must operate using scrap on a "worst-case-scenario" basis.

As scrap quality is undoubtedly a challenge for steel producers, the amount of scrap available is also problematic. Although specialists anticipate an increase in scrap worldwide, the amount of high-quality scrap will also decrease. The reason for this is two-fold. As electric steelmaking increases worldwide, scrap previously exported from certain regions will be processed and recycled domestically. This shift in scrap reuse will also mean that scrap will be recycled more often. Without optimizing the status of scrap processing, the number of contaminants and the quality of steel available as scrap will worsen over time. Thankfully, experts at Primetals Technologies are optimizing scrap processing by partnering with industry leaders like SICON.

CRAFTING THE FUTURE

Crafted scrap is the future of scrap-based steelmaking and will transform how producers manage and maintain their scrap yards. Crafted scrap is the end product and name for a comprehensive set of technologies making up a scrap preparation system. This system consists »

FIG. 2: Key features of the fully automated scrap yard

of hardware and software solutions, allowing the meltshop to control the scrap recipes sent to the melting unit, whether in converter or electric steelmaking, and even in the blast furnace. The benefit of this system is a centralized and controlled preparation of scrap that focuses on identifying the types of scrap being sent to the meltshop to ensure the appropriate scrap mix.

The system delivers exceptionally clean scrap by removing more than 99 percent of impurities.

GETTING SORTED

An integral part of crafted scrap is using scrap cleaning, pre-processing, processing, and sorting technologies from the cooperative partner of Primetals Technologies, SICON. SICON offers a range of products and expertise specializing in the sorting and cleaning of scrap. The EcoScan online is a robust solution for identifying and tracking scrap in the scrap yard, providing constant X-Ray analysis and connecting the scrap yard to an intelligent database for assessing scrap. Combined with solutions for sheared and shredded scrap, which utilize magnetic separation, air sifting, and automated sorting, their systems deliver exceptionally clean scrap by removing more than 99 percent of impurities and reducing copper content.

Where the EcoScan online aids with sorting scrap in the scrap yard, cameras and sensors from Primetals Technologies analyze and manage scrap set to be charged to the melting unit. Whether in a basket destined for the electric arc furnace or scrap chute destined for the converter, these solutions log and assess the exact scrap mixture tuned to the recipe required by the meltshop. The data is stored and utilized to ensure that the scrap is accurate within the chute. The scrap is then tracked and reassessed after loading to ensure it arrives at the appropriate melting unit. Once a camera detects a scrap chute, it will provide feedback recording the percentage and type of scrap within the chute and initiate a three-dimensional scan to assess the volume of scrap in the chute. This series of sensors, cameras, and trackers make up a system of checks to guarantee that the appropriate scrap arrives at the desired location.

DIGITAL FOUNDATION

At the heart of crafted scrap is the process optimization system from Primetals Technologies that integrates first and foremost with the production planning system, which controls the production plan, including the desired steel grades. A recipe is then pulled from a metallurgical database, including the type and amount

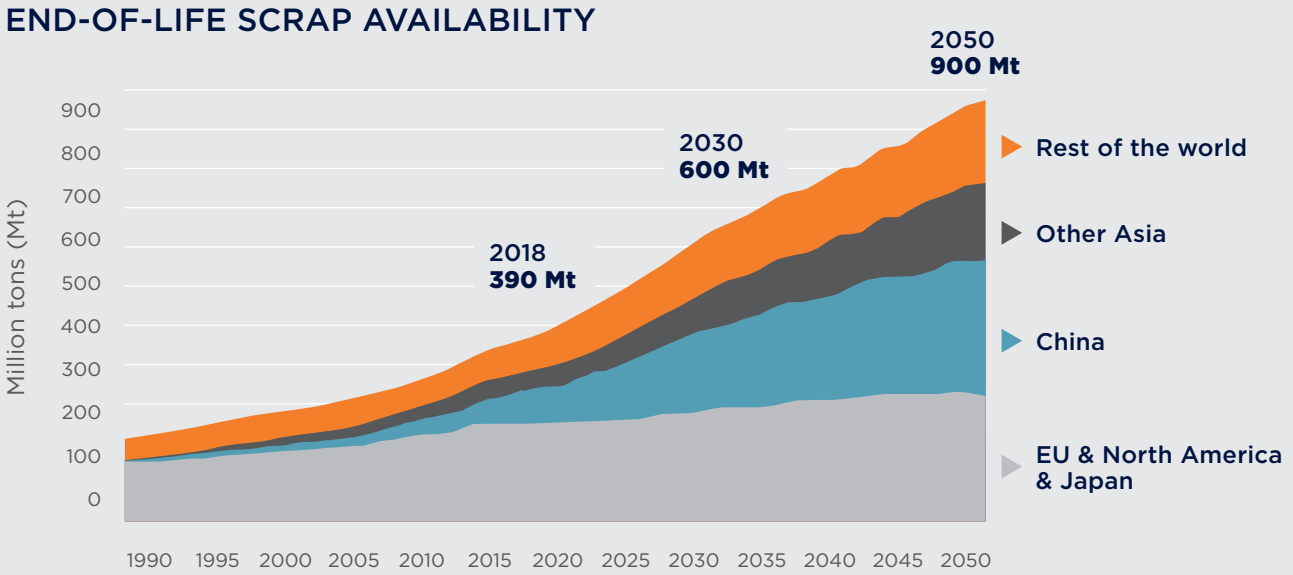


FIG. 3: worldsteel scrap availability model, September 2019 estimates in millions of tons until 2050

UNDERSTANDING SCRAP AND SCRAP CONTAMINANTS

Scrap regulations worldwide are diverse. They consist of varying qualifications and various standards. Common scrap types are heavy melting scrap or HMS 1 and 2. Consisting of iron and steel at the end of their lifetime, both HMS 1 and HMS 2 have various codes, according to the North American Institute of Scrap Recycling Industries. Regardless of their categorization, end-of-life steel often contains "tramp elements"—i.e., elements that cannot be extracted from molten steel. The most challenging elements are copper, tin, nickel, and molybdenum. The impact of these tramp elements on steel quality varies but has been known to lessen the quality of different steel grades. From controlling microstructures to steel properties, such as tensile strength, elongation, yield point, soundness in the welding area, and fracture toughness, have all been reviewed in terms of the impact of these elements. For copper, surface hot-shortness—i.e., cracking of the material's surface—is particularly concerning. Copper also limits the types of steel products to those with a higher tolerance—e.g., reinforcing bars.

of scrap required from the scrap yard. The scrap yard management system will update the optimization system with the latest scrap supply, including various scrap grades. Different rules are applied to the scrap yard and processing steps, including cutting, pre-shredding, shredding, cleaning, chemical analysis, and bailing based on the melting unit, converter, or electric arc furnace. Once completed, the scrap is charged to the melting unit, and the available stock at the scrap yard will also be updated.

FULLY OPTIMIZED AND FULLY AUTOMATED

The future of scrap-based steelmaking will be determined by optimized and efficient scrap processing capabilities applied to scrap yards worldwide. By increasing the quality of scrap delivered to melting units, scrap-based electric steelmaking could achieve higher steel grades than currently possible due to contaminants and impurities. The cleaning and sorting of scrap also saves steel producers valuable time, energy, and costs, as improved scrap quality means an increase in yield and a decrease in slag and CO_2 emissions. By integrating digital and automation systems into their scrap yards, steel producers can track, manage, and maintain highly efficient use of scrap with exceptionally high scrap rates decarbonizing and benefiting their production process.

Andreas Melcher, Product Lifecycle Manager Scrap Yard Automation, Primetals Technologies Austria

Heiner Guschall, CEO, SICON Germany

FIG. 1: Glowing electrodes of a ladle furnace

THE FUTURE OF **ELECTRIC STEELMAKING**

STEELMAKING IS IN THE PROCESS OF A REVOLUTION, AND ELECTRIC STEELMAKING IS AT ITS HEART.

With a long history of use in the steel industry, the electric arc furnace is emerging as a significant and essential player in the steel industry's future. With all eyes on green steel production, an electric arc furnace powered by renewable energy offers the optimal route for carbon emissions reduction. The advantages of an EAF are numerous, and EAFs today boast capacities and steel-grade production capabilities that parallel the BOF. With its diverse portfolio, Primetals Technologies is helping define the future of electric steelmaking.

Steel producers worldwide are pursuing a means to decarbonize, maintain, and advance their plants. While the integrated blast furnace–basic oxygen furnace route remains dominant, diverse producers and future-oriented industry leaders recognize the need for new steel production. Albeit a technology with its foundation in a long history of steelmaking since the early 1900s, the electric arc furnace has come a long way in the past century, and today's furnaces would seem impossible from the earliest ratings of 500 kilowatts and 4-ton capacities. At Primetals Technologies, the electric arc furnace is a critical player in the future of steelmaking.

THE EMERGENCE OF ELECTRIC STEELMAKING

Before delving into what makes electric steelmaking a vital part of the steel industry's future, understanding the history of the electric arc furnace and its functions is worth a brief explanation. While the first successful experiments of an electric arc date back to 1808, it was in 1900 that the first commercial application of the direct arc steelmaking furnace took place. The first furnaces were adopted in North America, in both the U.S.A. and Canada. In just 20 years, the capacities of electric arc furnaces went from 4 tons to 15-20 tons using automatic regulators and, decades later, replacing carbon electrodes with graphite.

Electric arc furnaces saw greater adoption after World War II. Thanks to their construction and ability to integrate into minimills, steel produced via an electric arc furnace makes up nearly one-third of global steel production today. Reports anticipating the future of the steel industry and a rise in green steel production suggest that China's electric steel production will rise to 20 percent of steel production by 2030. Such a rapid increase in electric steelmaking aligns with increased scrap consumption to aid in the decarbonization of the steel industry.

SCRAP PREHEATING

Alongside an increase in electric steelmaking in the future, scrap melting in an electric arc furnace provides steel producers with a primary means of reducing their carbon emissions efficiently and effectively. Yet, beyond the benefit of carbon emissions reduction, electric arc furnaces also offer efficient tap-to-tap times increasing productivity. The EAF Quantum by

FIG. 2: Controlling the arc and temperature of an electric arc furnace is key to efficient production.

With scrap preheating and the Furnace Advanced Slag-free Tapping system, the EAF Quantum offers efficient and lightning fast tap-to-tap times and increased capacities.

Primetals Technologies provides producers with a swift tap-to-tap time of just 33 minutes. However, this is just one benefit of the EAF Quantum.

Recognizing the relevance of scrap melting for electric steelmaking, specialists at Primetals Technologies developed the EAF Quantum with an innovative scrap preheating method. A shaft captures the off-gas from furnace operations and redirects it to a section containing scrap prepared to be charged to the hot metal bath of the EAF. Equipped with an elevator that lifts the scrap chute, transportation logistics also benefits from EAF Quantum's operation. By preheating the scrap, energy savings are also a factor as the workload of the electrodes is spared the necessity of heating room temperature scrap. Considering the additional Furnace Advanced Slag-free Tapping (FAST) system, the EAF Quantum has lightning-fast tap-to-tap times, increasing overall production capacities.

DIGITAL, AUTOMATED, RELIABLE

While an electric arc furnace presents clear benefits in cost, return on investment, production capacities, and environmentally friendly steel production, one clear additional advantage is how EAFs integrate seamlessly with practical digital and automation tools. One clear example is the Melt Expert from Primetals Technologies. Able to control both the EAF and ladle furnaces, the Melt Expert allows for the accurate reproduction of a specific melting process by controlling the electrodes based on production data.

Operators can inspect the melting process using a clear and accessible interface using historical and real-time

PIONEERING ELECTRIC STEELMAKING

Head of Electric Steelmaking at Primetals Technologies, Dr. Hans-Jörg Krassnig, is focused on expanding and revolutionizing electric steelmaking at Primetals Technologies.

What role will electric steelmaking play in the coming decades?
Hans-Jörg Krassnig: A major role. The trend to substitute integrated steel plants with EAF-based meltshops will expand with increased requirements to decarbonize the industry. With EAF-based steelmaking, the CO_2 reduction potential is more than 90 percent using crafted scrap, hydrogen-based DRI, renewable powered EAFs, and increased deployment of CCUS.

What sets electric steelmaking at Primetals Technologies apart?
Krassnig: It is the people, the specialists at Primetals Technologies, that sets us apart. Specialists who bring comprehensive expertise in ancillary systems, environmental technology, logistics, assembly, project management, and automation and digitalization.

What is on the horizon for electric steelmaking? Where are we headed?
Krassnig: High-quality steel-grade production using EAFs will be key in the near future. Knowledge about raw materials and scrap, and digitalization of all process steps will support improvements in product quality, by making the electric steelmaking process more transparent. Our task is to deliver groundbreaking solutions to redefine high-quality EAF-based steel production.

ARC CONTROL: ACTIVE POWER FEEDER

Electricity has always been a fascinating marvel of modern technology. Since the legendary observation of lightning by Benjamin Franklin, electricity has done nothing short of inspiring technologists and scientists for generations. And while it is indeed a powerful force, controlling it would be the equivalent of "catching lightning in a bottle," and Primetals Technologies has done just that.

CLEAN, STABLE ENERGY

The Active Power Feeder by Primetals Technologies is a means of controlling the uncontrollable, that is, the power from the grid to the electric arc furnace. The Active Power Feeder provides seamless control and targets specific arc lengths with impeccable precision. By regulating the incoming electrical power, the arc within the EAF can maintain consistent power levels regardless of the grid's energy quality. Constant power levels in different process phases mean that heats and melting rates can all be controlled and maintained consistently. And the arc control is also integrated into the Melt Expert, providing immediate feedback and improving using historical and real-time data.

GRID CONTROL

While controlling the arc in the EAF is essential, proper power regulation on the operations side is equally important for reducing flicker and keeping the power grid clean. In particular regions, this is extremely important as it ensures minimal disturbances to the grid, which often incurs unanticipated costs for the steel producer. Moreover, flicker is a problem during operations because an influx or irregularities in the arc decreases efficiency. The Active Power Feeder is the ideal solution for electric steelmaking and is, in its design and implementation, unique to Primetals Technologies. The Active Power Feeder is the perfect solution for electric steelmaking, offering complete control and regulation of the arc and incoming and outgoing power.

meta.ls/pioneers-talk15

PIONEERS TALK #15:

LIVING AND BREATHING ELECTRIC STEELMAKING

In this session of Pioneers Talk, Dr. Hans-Jörg Krassnig provides an inside look at electric steelmaking at Primetals Technologies. Fascinated by the raw power of the solutions he specializes in, Krassnig has spent more than 20 years in this field.

SALCOS: SALZGITTER LOW CO_2 STEELMAKING

Salzgitter has joined forces with industry partners and researchers to lay the foundations for a "virtually CO_2-free steel production." Focusing their attention on carbon direct avoidance, the crucial elements of the project involve electricity from renewable sources and the production of hydrogen using electrolysis to create green hydrogen. Using hydrogen as an iron-reducing agent is key to their goals, as well as increasing the utilization of scrap and completing refinement in an electric arc furnace.

data. The algorithms informing Melt Expert will also adapt based on energy requirements and dynamically adjust the process. In summary, Melt Expert controls the melting process and works ideally with the power solution Active Power Feeder, which provides precision control of the arc itself while also keeping a clean grid. Producers can thus reduce energy consumption and increase productivity and reliability by using these solutions in tandem with their electric arc furnaces.

THE FUTURE IS ELECTRIC

While this is only a brief overview, what's clear: the future is electric. The industry is trending toward electric steelmaking, and developments at Primetals Technologies are here to facilitate this transition. Already the trend toward electric steelmaking is taking hold around the world. For example, in Germany, steel producer Salzgitter has committed to its transformation toward electric steelmaking, investing in an EAF Ultimate with a tapping weight of 220 tons combined with the world's largest waste heat recovery system. As part of their low-carbon initiative—i.e., the Salzgitter Low CO_2 Steelmaking (SALCOS) project—their entire production will transform by 2033.

The project will total three electric arc furnaces, and two direct reduction plants will completely replace Salzgitter's existing blast furnaces and converters. However, this is just one example of the types of transitions on the horizon. Other producers are also looking at transforming their production processes, and electric steelmaking plays a central role. Whether parallel operations alongside converters or a complete transformation, the revolution of electric steelmaking has genuinely begun and will define the steel industry's future. |

Dr. Hans-Jörg Krassnig, Head of Electric Steelmaking
Adam Merki, Lead Editor
(Both with Primetals Technologies Austria)

ENDLESS STRIP PRODUCTION **ARVEDI ESP MEANS GREEN STEEL**

ARVEDI ESP IS THE ONLY CASTING AND ROLLING TECHNOLOGY OFFERING REDUCTION IN CO_2 EMISSIONS TO NET-ZERO AND PRODUCING DIRECT-APPLICATION END PRODUCTS.

While steel producers face the global challenges of climate change and seek environmentally friendly technologies, Arvedi ESP is the only proven means of green steel strip production. Since 2009, Arvedi ESP has set the standard for thin and ultra-thin direct-application end products while maintaining and improving on a minimal carbon footprint.

FIG. 1: Henan Yaxin's environmentally friendly mini-mill featuring EAF Quantum and Arvedi ESP

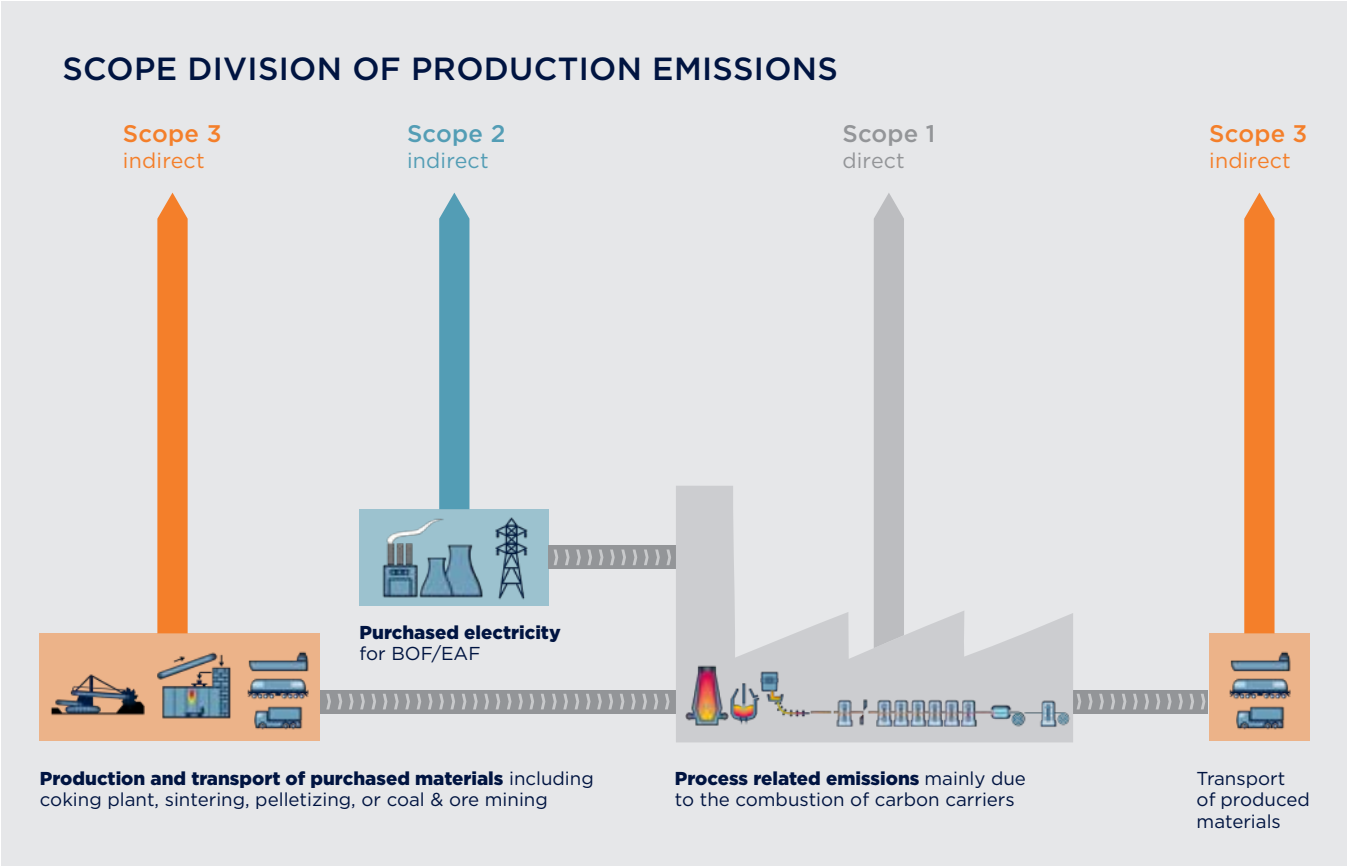


FIG. 2: Scope division of production emissions

While it may be hard for some to imagine such an innovative technology for reducing CO_2 emissions, low energy consumption, and reduced operational expenditures to have been around since 2009 and only improved since then, Arvedi ESP is such a technology. What began as the groundbreaking vision of Italian inventor Giovanni Arvedi has become one of the most innovative and adopted technologies on the market for Endless Strip Production. Since Arvedi's vision began, nearly two decades ago in 2006, and after the first demonstration of Endless Strip Production in 2009, the planet has undergone immense changes. Among those changes are a global awareness of climate change and an appeal to heavy industries worldwide to transform and adapt to a changing landscape.

CLIMATE CHANGE WORLDWIDE

As the effects of climate change become more apparent year after year, governments have thankfully chosen to work together toward a mutual goal to tackle this imminent crisis. During the 21st Conference of the Parties (COP21) in 2015, the Paris Agreement to limit global warming to 1.5 degrees Celsius marked the first legally binding international treaty on climate change. In 2021, world leaders renewed their commitment to climate change during COP26 in Glasgow, United Kingdom with 153 U.N. members putting forward net-zero emissions targets. For example, the E.U. and U.S.A. have agreed to net-zero emissions by 2050 and China and Brazil by 2060. During COP27 in Sharm el-Sheikh in 2022, further financial goals and commitments were established and reestablished.

In the E.U., the European Green Deal has declared a reduction in emissions by 55 percent until 2030. As the decade progresses toward 2030, international legislation and regulations will seek to effectively motivate carbon-intensive sectors toward carbon neutrality, such as the energy and steel industries. While these regulations may appear to be inconvenient hurdles, innovators in these sectors that are willing to invest in readily available technologies will reap the rewards of green production.

UNDERSTANDING CARBON EMISSIONS

Amidst growing concerns regarding climate change, steel producers must find solutions to reduce CO_2 emissions while maintaining production capacities and meeting increasing demands for high-strength steels. These concerns are not only limited to the cost of pro-

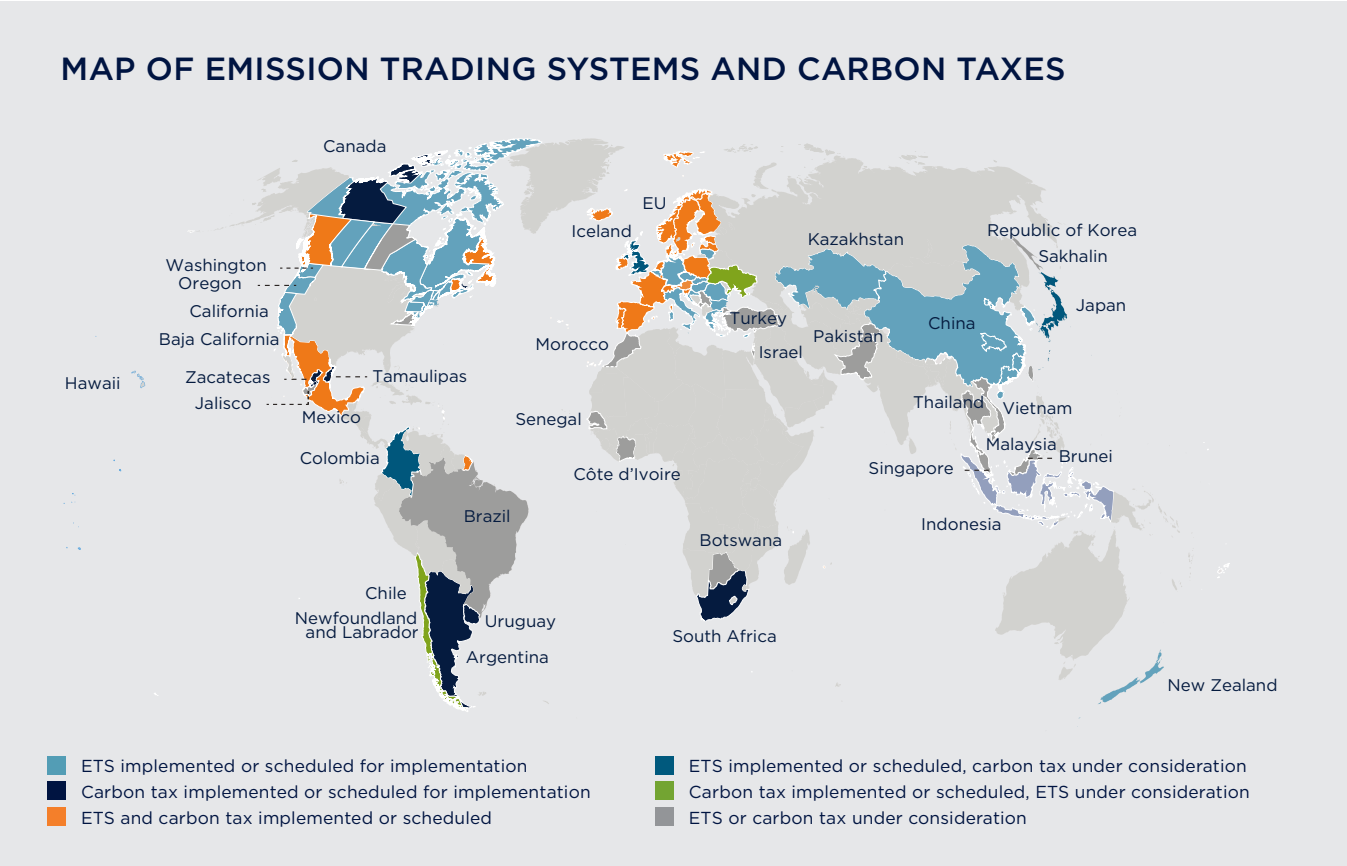


FIG. 3: Carbon pricing initiatives implemented, scheduled for implementation, and under consideration (ETS and carbon tax, 2021). World Bank Group, "State and Trends of Carbon Pricing 2021," Washington D.C., U.S.A., 2021

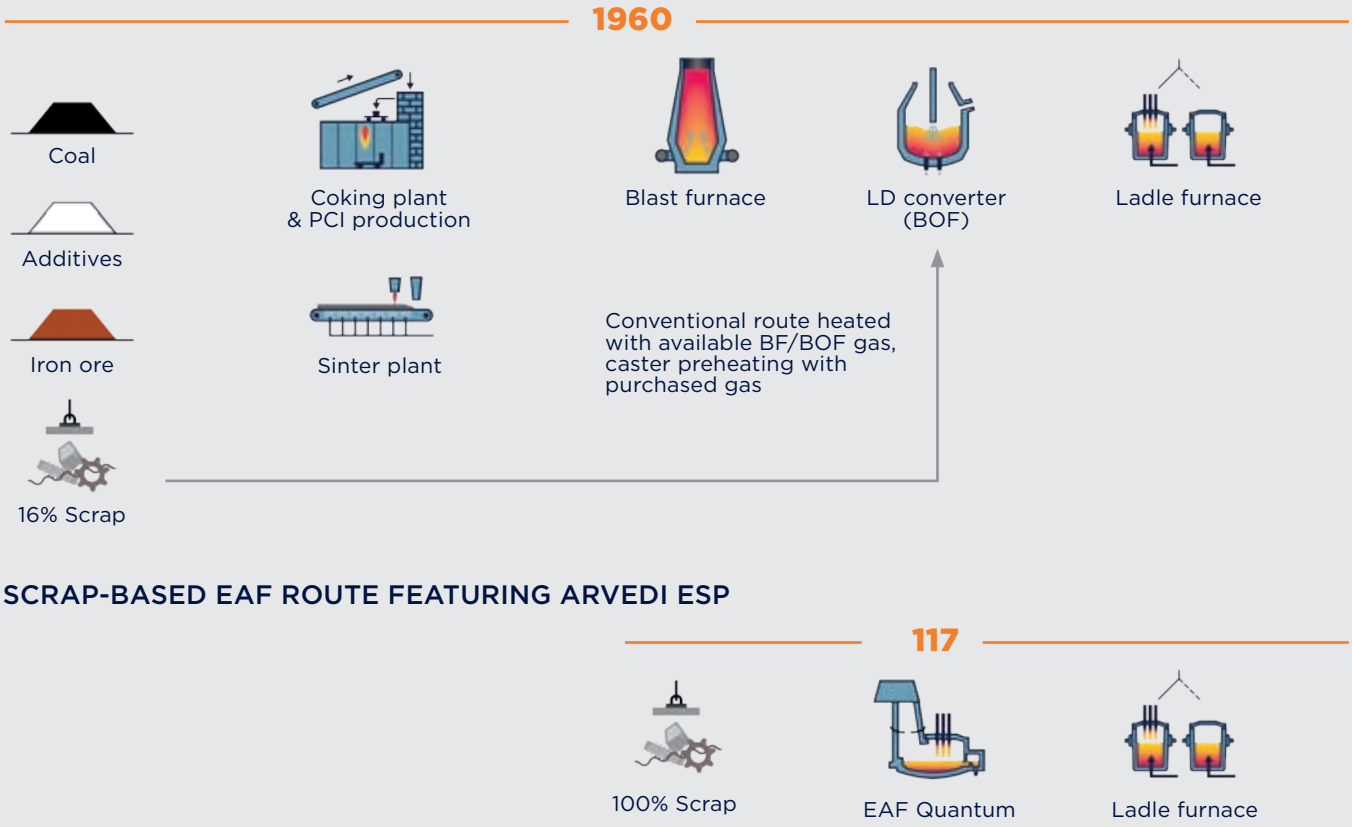
duction based on raw materials and energy consumption but also the imminent implications of the E.U.'s Emission Trading System (ETS) and the related Carbon Border Adjustment Mechanism (CBAM). Yet, while these systems appear daunting, a brief understanding of how they apply to technologies, such as Arvedi ESP and steel production, may help appreciate their value and potential to increase competitiveness worldwide.

Amidst growing concerns regarding climate change, steel producers must find solutions to reduce CO_2 emissions and maintain capacities.

To state it plainly, the primary focus of CO_2 emission reduction for global ETS and carbon tax systems is Scope 1 emissions. Scope 1, 2, and 3 emissions include those emissions produced by the company directly (Scope 1), those emissions produced from the company's energy consumption (Scope 2), and, finally, emissions produced indirectly in upstream and downstream processes (Scope 3). Thus, when calculating the impact of various carbon taxes, steel producers must look primarily toward reducing their Scope 1 emissions.

To this end, a traditional steel production route, including ironmaking utilizing a blast furnace, BOF steelmaking, casting, hot rolling, and cold rolling, would amount to the total direct emissions of a steel producer, or Scope 1. The amount of electricity used is indirect emissions, or Scope 2. Scope 3 includes the production and transport of raw materials and the transportation of the finished products (see Figure 2). If any of the input materials, electricity, or shipment is handled by the same company, then it stands to reason that »

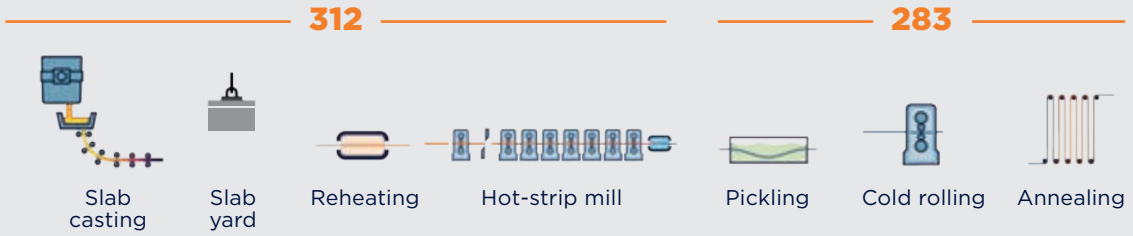
REDUCTION IN AVERAGE CO_2 EMISSIONS USING ARVEDI ESP



these may be calculated and transferred over company borders accordingly. To prevent leakage, CBAM in the E.U. also ensures that producers pay carbon taxes on goods imported into the E.U.

For the E.U., CBAM is just one example of carbon pricing initiatives emerging throughout the globe. While carbon prices may vary from country to country and emissions categorically differ depending on specific regulations, the cost of emissions will continuously rise. In The World Bank's investigation from 2021, the price of CO_2 reached 137 dollars per ton in Sweden. While pricing schemes vary, the E.U. Carbon Permits have seen a steady increase. At the start of 2022, the price of Carbon Permits reached 97.50 euros. Amidst this array of measures taken to motivate industries to decarbonize, one thing remains clear, the cost of CO_2 emissions will steadily rise, and while some loopholes remain, transitioning to low-carbon and carbon-neutral solutions will make or break industry leaders.

The efficient and ultra-compact Arvedi ESP line boasts a 45 percent lower energy consumption than conventional casting and rolling plants.



2555
kg of CO_2 per ton of steel

-95%

-2432
kg of CO_2 per ton of steel

Comparison of average CO_2 emissions of an integrated steel production route and an optimized scrap-based EAF/ESP route. In the center of the figure, one notes that the traditional process—slab casting, slab yard, reheating, and hot-strip mill—is substituted below by Arvedi ESP. The difference shown in kilograms of CO_2 per ton of steel is 312 versus 2, which means Arvedi ESP reduces emissions to practically zero.

123
kg of CO_2 per ton of steel

ARVEDI ESP MEANS GREEN STEEL

While the adoption of low-carbon and zero-carbon technologies often involves an investment in technologies that have yet to prove their mettle, Arvedi ESP is unique amongst such technologies. Arvedi ESP is a proven "currently available technology," according to the E.U. Policy Department for Economic, Scientific, and Quality of Life Policies. In their publication "Moving towards Zero-Emission Steel," they found that incorporating "near-net shape casting," such as Arvedi ESP, can substitute the conventional hot rolling process, representing approximately 20 percent of the emissions from steel production. According to the same report, the CO_2 reduction capabilities of all available near net shape casting technologies average a 60 percent decrease in emissions via a reduction in energy consumption, according to reports by ICF Consulting Services from 2019. When looking at the overall impact of Arvedi ESP, the numbers amount to even greater potential.

From the beginning, the efficient and ultra-compact Arvedi ESP line boasted the lowest possible energy consumption than conventional casting and rolling plants. When combined with liquid steel supplied from an EAF Quantum with optimized melting technology, operational costs, CO_2 emissions, and energy costs are all reduced. This technology combines well with the scrap use and renewable energies to reach the most stringent levels of environmentally friendly production. This combination ultimately amounts to a scrap-based EAF/ESP route that produces 95 percent fewer CO_2 emissions (see box above). Suppose we zoom in to the difference between Arvedi ESP and a traditional continuous casting, reheating, hot-strip mill production route. In that case, Arvedi ESP means 99 percent fewer emissions than the conventional route—the maximum reduction in emissions from this portion of steel production, also reducing operational expenditures, overall carbon footprint, and space required for such an operation. »

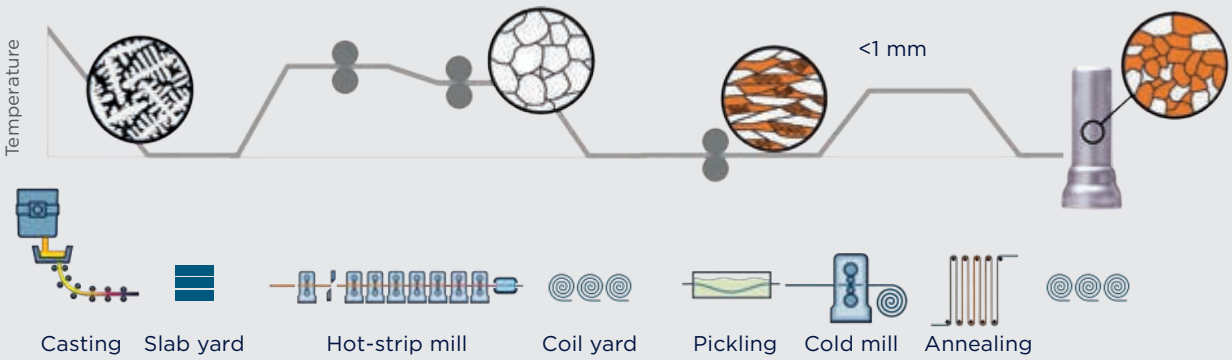
ARVEDI ESP FOR **DIRECT-APPLICATION PRODUCTS**

In conventional production processes, a steel sheet is produced over several steps where the material cools down to ambient temperature after casting and is reheated for hot rolling. After cold rolling to the required thickness below one millimeter, the steel is heated again for annealing. Once these these steps have been completed, the material is ready for application.

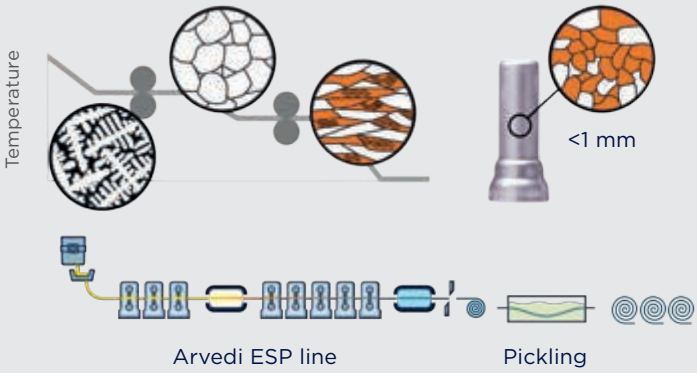
The Arvedi ESP process performs casting and rolling down to a minimum thickness of 0.6 millimeter in a single step lowering energy requirements to a minimum. The hot-rolled Arvedi ESP material fulfills all comparable cold-rolled material requirements and can thus be directly applied. The illustration demonstrates how Arvedi ESP compares when producing low-carbon forming steel grades.

COMPARISON OF CONVENTIONAL AND ARVEDI ESP ROUTES FOR LOW-CARBON FORMING GRADES

Conventional production route



Arvedi ESP route for production of direct-application strip



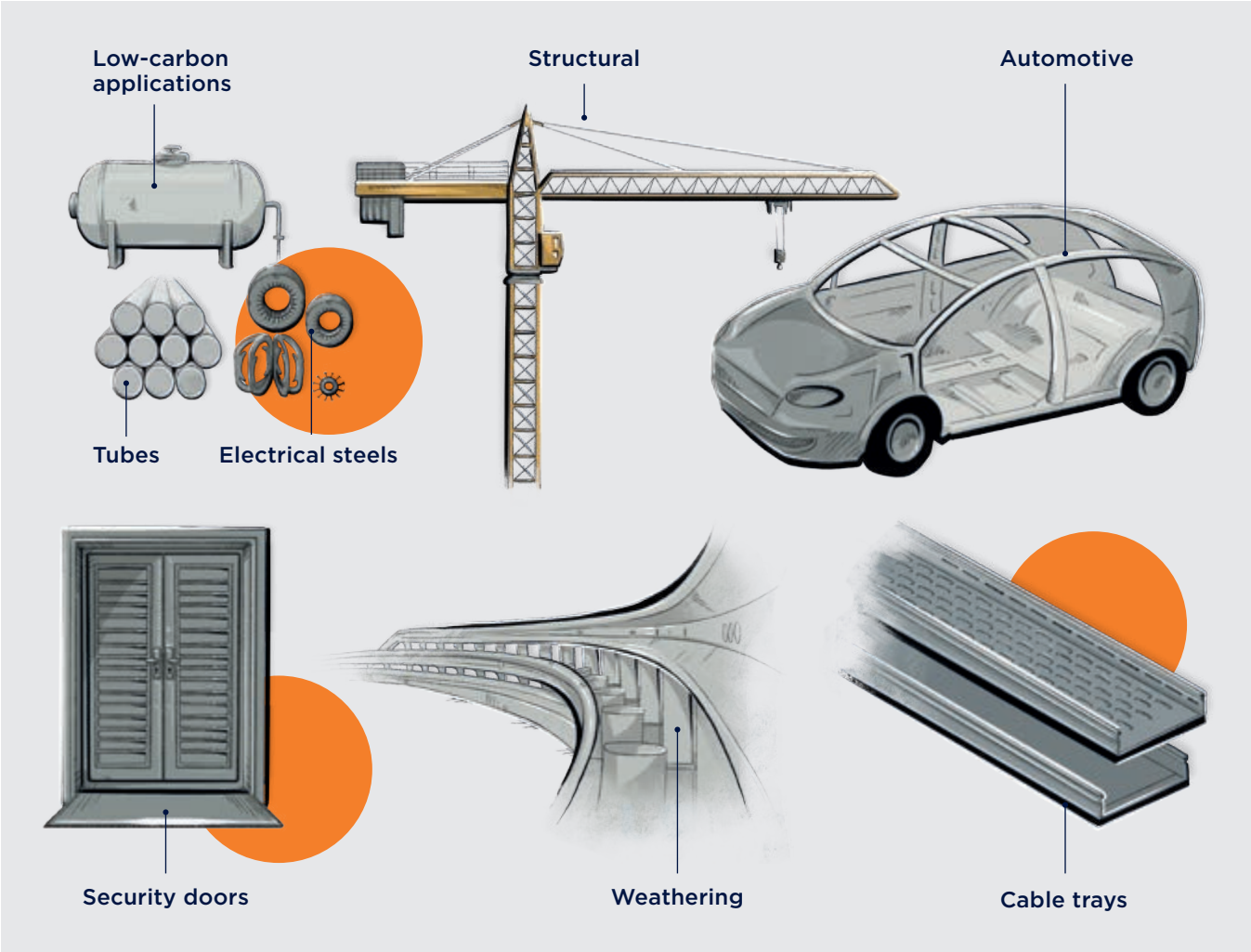


FIG. 4: Direct-application steel is used in many sectors, e.g., security doors, structural steel products, cable trays, cabinets, weathering steel, and low-carbon and high-strength low-alloyed (HSLA) applications. The automotive sector, with various applications, is of particular interest for ESP production.

ENDLESS INNOVATION

The minimill of the future is already in operation since 2021 by Chinese steel producer Henan Yaxin. The entire production route, from scrap to cold band substitute, produces 123 kilograms of CO_2 per ton of steel. With two EAF Quantum electric arc furnaces and an Arvedi ESP line at its Fujian Dingsheng plant, Henan Yaxin produces high-quality, ultra-thin strip ready to enter new market segments with direct-application products. Henan Yaxin sets a new environmental benchmark for steel production by omitting cold rolling, annealing, and related emissions. The minimal energy requirement of this minimill for flat products contributes to a 95 percent reduction in CO_2 emissions and a reduction in operating costs.

As climate change and resulting countermeasures present more and more challenges to steel producers, change is an opportunity for businesses to improve. Reliable technologies for low emission steel production, reducing overall emissions, have been available for years. When laying the groundwork for new and modernized installations, green technologies like Arvedi ESP and the EAF Quantum are a chance for steel producers to anticipate upcoming changes presented by legislation and emerge as frontrunners in green steel production. The concept of modular transitions, replacing superfluous production steps with ESP, expedites a transition of the existing production process to a more environmentally compatible steelmaking process. For the production of high-quality steel, combined green steel solutions from Primetals Technologies mean an endless return on investment for years to come. |

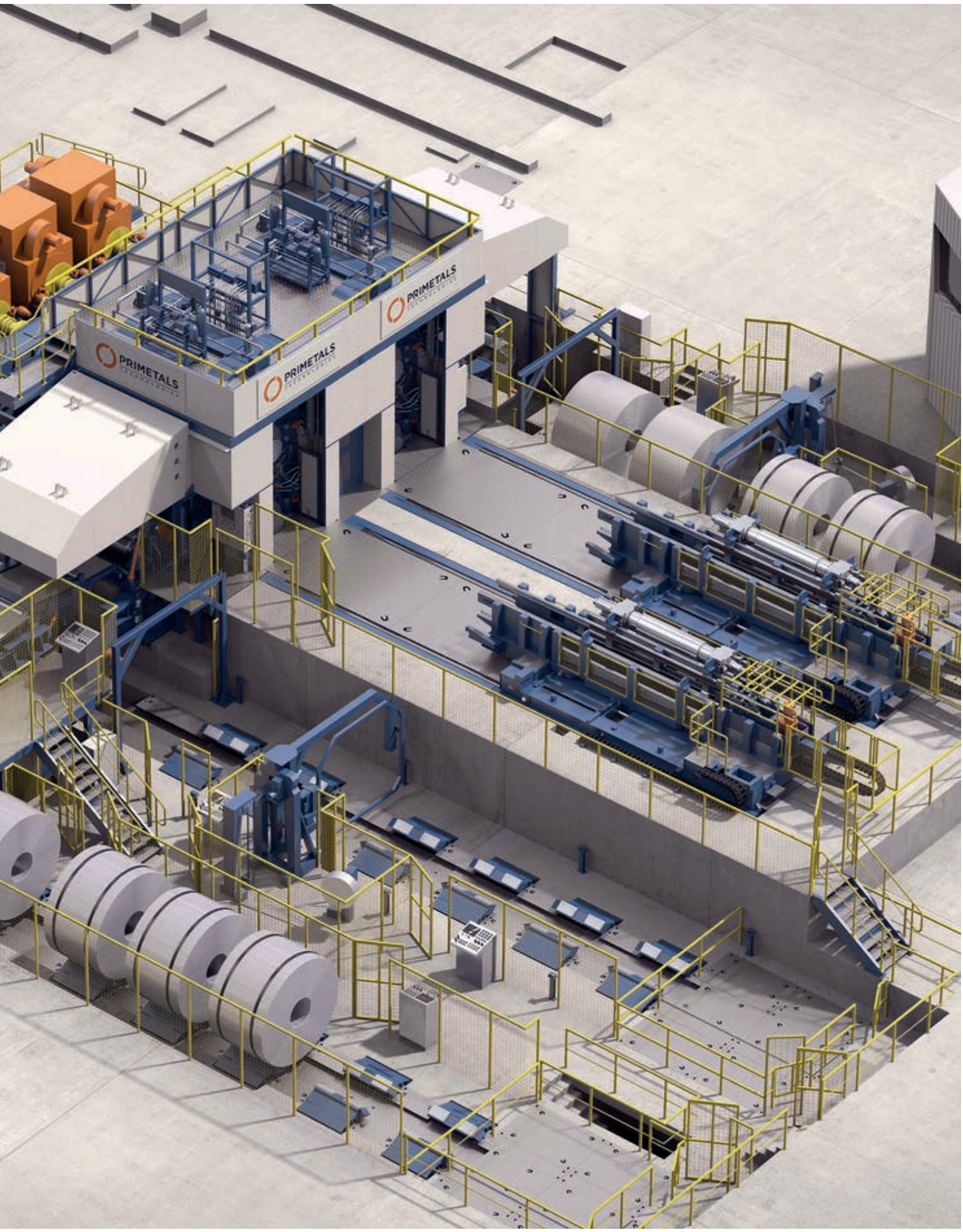
Andreas Jungbauer, General Sales Manager, Endless Strip Production
Adam Merki, Lead Editor
(Both with Primetals Technologies Austria)

MEETING DEMAND ELECTRICAL STEEL AND E-MOBILITY

THE FUTURE OF E-MOBILITY MEANS IMPROVED ELECTRICAL STEEL.

From grain-oriented to non-grain-oriented, from thin to ultra-thin, electrical steel grades are as strong, lightweight, and precise as they are essential to the future of e-mobility. Cold rolling technologies that work to maximize output while maintaining and improving the quality of electrical steel grades are vital to meet increasing demands.

FIG. 1: A 2-stand Hyper UC-Mill, ideal for the production of non-grain oriented electrical steel and advanced high-strength steel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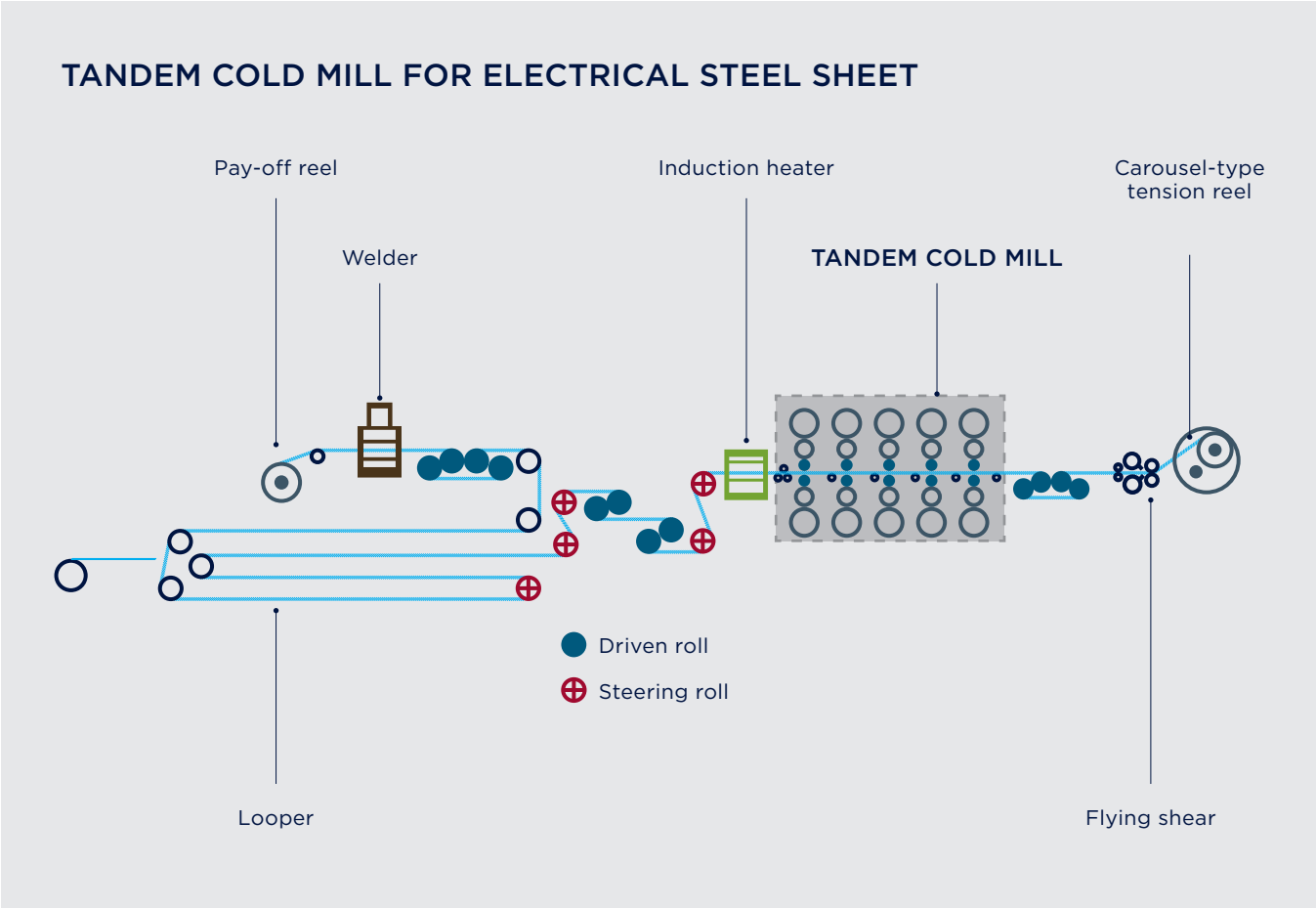


FIG. 2: The typical configuration of a tandem cold mill

The steel industry is not alone, as many global initiatives focus on decarbonization. For the automotive sector, electrification is the future of mobility. The corresponding growth in e-mobility for the automotive industry will also signal increased demand for electric steel grades from the world's steel producers. Thin-gauges, high-permeability, grain-oriented, and non-grain-oriented, these steel grades are challenging to produce, and the industry will be pressed to maintain quality while increasing capacity. Thankfully, solutions and technologies for rolling these extremely hard materials exist, and even more improvements are on the horizon.

THE FUTURE OF MOBILITY

Electric vehicles, or EVs, have increased since 2020 when Europe saw adoption reach eight percent. While several countries have announced a sales ban on internal combustion engine vehicles by 2030 or 2035, the E.U. and U.S.A. aim for EVs to make up 50 percent of cars by 2030. Consumer benefits, such as tax breaks, have already been implemented to motivate the transition to electric cars. Today, individuals are also more conscious of sustainability. Moreover, as e-mobility improves and expands, the automotive sector will encourage change in adjacent industries impacting infrastructure, energy, and steel.

The conventional internal combustion engine car contains approximately 25 to 30 kilograms of silicon steel. On the other hand, EVs have a light steel body structure to reduce the overall mass of a vehicle and greenhouse gas emissions. Yet, by replacing the combustion engine with a light and highly efficient electric motor, car manufacturers have effectively doubled the amount of silicon steel per car to anywhere from 60 to 70 kilograms. With the most prominent automotive markets slated to become entirely electric by 2035, electrical steel will become more than a niche product. Add to that the silicon steel used in the manufacture of electrical appliances, and you will arrive at a projected market growth for electrical steel of 7.5 percent by 2027.

THIN, STRONG, ELECTRIC

Electrical steel refers to electric steel grades containing anywhere up to 6.5 percent silicon. Typical commercial grades have up to 3.2 percent. Increased

ROLLING CAPABILITIES

Mill configuration		RCM	RCM / TCM	RCM / TCM
		20 Hi HZR	HYPER UCM	Standard UCM
Mill type				
Work-roll diameter		Very small	Small	Medium
Non-grain-oriented	Low & medium (NGO)	Applicable	Recommended	Recommended
	High grade (HNGO)	Recommended	Recommended	Applicable
Grain-oriented	Low & medium (GO)	Recommended	Partially applicable	Not applicable
	High grade (HGO)	Recommended	Not applicable	Not applicable

FIG. 3: Rolling capabilities and products according to their associated mill technologies, including reversing cold millls (RCM) and tandem cold mills (TCM)

A Hyper UC-Mill can reach a work roll diameter to a maximum strip width ratio of 20 percent. This ratio is ideal for high-silicon electrical steel, such as, high-permeability non-grain-oriented.

amounts of silicon mean an increased degree of electrical resistance. These steels are also typically rolled to thin and ultra-thin thicknesses—i.e., 0.25 millimeters and below. They are characterized by their thinness, strength, and silicon content. However, all these factors impact the workability of the metal during rolling due to increased hardness and brittleness. Thus, rolling these steel grades poses significant additional challenges for steel producers.

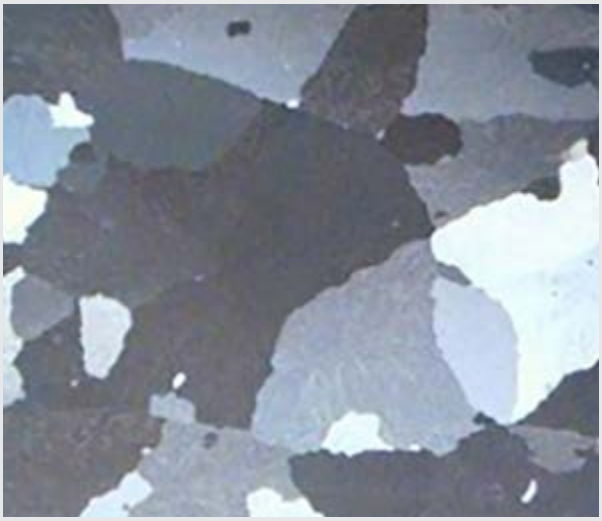
Some of the challenges facing the cold rolling of these particularly fragile steel grades include the deformation of work rolls, non-uniform thickness profiles—particularly at the edge of the strip, known as edge drop—, edge cracks, and heat streaks. Combine these difficulties, which either slow production or reduce quality, with a growth in demand, and steel producers must meet exceptionally high-quality standards and increase yield without running into these problems.

PERFORMANCE UNDER PRESSURE

Solutions for rolling thin electrical steel grades brought about the adoption of the UC-Mill to produce thin »

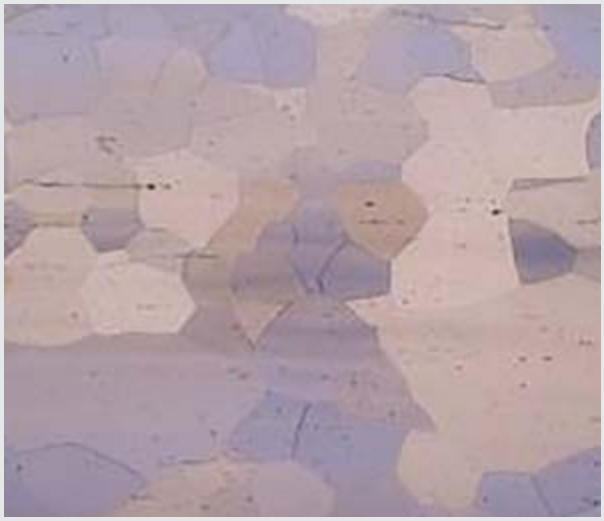
A GRAIN OF TRUTH

Microstructures of grain-oriented and non-grain-oriented reveal the inner workings of these essential types of electrical steel.



Grain-Oriented Electrical Steels

As the name suggests, grain-oriented electrical steel grades involve the consistent, uniform direction of grains in its structure. This uniformity makes for increased magnetism. Grain-oriented electrical steels are commonly used in transducers and magnetic applications, where the direction of magnetism is known and predictable.



Non-Grain-Oriented Electrical Steels

Like grain-oriented steels, non-grain-oriented electrical varieties are valuable for their magnetic properties. However, non-grain-oriented steel grades possess magnetic tendencies in all directions. Unlike their grain-oriented counterparts, the grain structure is random. These steels are commonly found in motors, generators, and alternators.

materials with less force. Less force reduces the chances that the work rolls will deform during cold rolling. Taking things one step further, Primetals Technologies developed the Hyper UC-Mill, a 6-high Universal Crown Control Mill with work rolls approximately 20 to 40 percent smaller than those of the standard UC-Mill, which allows for higher reduction ratios. A Hyper UC-Mill can reach a work roll diameter to a maximum strip width ratio of 20 percent. This ratio is ideal for rolling high-silicon electrical steel grades—e.g., high-permeability non-grain-oriented electrical steels—and even advanced high-strength steels (AHSS).

Yet, decreased work roll diameter is not the only improvement to the work rolls in a Hyper UC-Mill. Quite a bit of innovation was done additionally, as the Hyper UC-Mill combines work roll shifting, intermediate roll shifting, work roll bending, and intermediate roll bending to achieve precision edge drop and flatness control. The hydraulic cylinders compensate by "shifting" the work rolls to achieve consistent rolling pressure and flatness. Shifting maintains a constant reduction ratio and profile, meaning improved flatness.

BRINGING THE HEAT

While adding heat to the cold rolling process may seem contrary, applying heat via an induction heater can help reintroduce vital workability to the steel strip. As previously mentioned, the high silicon content of electrical steel grades—i.e., silicon percentages greater than or equal to 2.5—creates an increased risk of breakage due to its brittleness. It may also suffer from edge cracks, which slow production. These issues may occur more commonly when rolling at room temperature.

By applying heat to the steel strip and increasing the temperature to anywhere from 60 to 160 °C, producers can effectively produce "warm rolling" conditions in the first pass of a tandem or reversing cold mill. Warm rolling ensures that increased speed or deformation rates will not translate to strip breaks—and therefore leads to improved productivity and production rates for high-silicon electrical steel. However, while adding heat provides one solution, maintaining the temperature of the strip is more than essential.

MINIMUM QUANTITY, MAXIMUM RESULTS

Strip reheating through an induction heater may provide one solution when rolling electrical steels, but this is a symptom of a more significant challenge—temperature control. If a strip is too cool, edge cracks and strip breaks may occur, and if a strip is too hot, heat streaks or surface defects may emerge. Strip temperature is maintained using various mechanisms throughout the rolling process, including strip cooling, work roll cooling, strip speed, rolling pass distribution, and induction heating. However, keeping these factors in order is challenging for even the most skilled operator.

When applying work roll cooling, emulsion lubrication is an effective means of maintaining temperature but can have adverse effects, particularly when trying to achieve "warm rolling" conditions. Ensuring the minimum amount of lubrication is utilized, Minimum Quantity Lubrication by Primetals Technologies uses atomized rolling oil sprayed onto the surface of the work rolls. It creates an oil layer on the work roll surface to improve friction conditions. A thin oil layer means the strip temperature remains unaffected. With less friction and a layer of oil for insulation, strip temperature can remain constant during rolling. Combining state-of-the-art lubrication and temperature control system increases efficiency, reduces costs, and improves the consistency of the product.

THINNER AND FASTER

With e-mobility and EV adoption on the rise, electrical steel grades will become increasingly prevalent in the steel market. However, with increasing demand, there will also be greater emphasis on quality, consistency, and thinness. Producers will be challenged to deliver high-quality electrical steel with speed and precision. The Hyper UC-Mill can improve strip thickness reduction and quality, and combining Hyper UC-Mills in a Tandem Cold Mill configuration means getting thinner faster. But while most Hyper UC-Mills can meet the application for various types of non-grain-oriented electrical steels, a ZR-Mill offers the opportunity to go even thinner with harder materials.

The typical ZR-Mill also came with challenges regarding quality, efficiency, and other shortcomings. For these reasons, Primetals Technologies also developed a split-housing ZR-Mill, known as the HZ-Mill. With a large gap opening for easy strip threading, a flexible roll diameter configuration, and various other improvements, Primetals Technologies sets the standard for UC- and ZR-Mills. The Hyper UC-Mill and HZ-Mill both offer consistent quality and efficient production of grades of grain-oriented and non-grain-oriented electrical steels to meet the growing market demands for years to come. |

Ichiro Maeno, Head of Global Business Unit Downstream, Primetals Technologies Japan

Dr. Konrad Krimpelstätter, Head of Innovation & Technology for Hot and Cold Rolling, Primetals Technologies Austria

meta.ls/pioneers-talk11

PIONEERS TALK #11:

E-MOBILITY IS HERE, BUT NOW WHAT?

Watch a new episode of Pioneers Talk featuring Dr. Konrad Krimpelstätter. Find out more about e-mobility and increased demand for lighter and stronger steel. Dr. Kimpelstätter explores the impact of this demand on the industry today, and tomorrow.

WHERE SAMBA **MEETS SERVICES**

The workshop at the Rio de Janeiro location employs a staff of 300.

RIO DE JANEIRO IS THE FEATURED COMPANY LOCATION IN THIS EDITION OF METALS MAGAZINE

LONDON · SAVIGNEUX · DROGENBOS · WILLSTAETT · ERLANGEN · LINZ · OSTRAVA · CRACOW · OULU · ISTANBUL · KIEV · MOSCOW · DUBAI · EKATERINBURG · MUMBAI · KOLKATA

Rio de Janeiro is known for its exuberant cultural assets—such as Samba, the Carnival, and the statue of Cristo Redentor. But the city is one of many faces. While the local population and tourists all appreciate the beautiful beaches, the seaside connection is also of great benefit to the steel industry. The Primetals Technologies company location in Santa Cruz, part of Rio's West Zone, operates one of the company's largest metallurgical services workshops. Editor-in-Chief Dr. Tom Widter reports from Brazil.

"Cabin crew, prepare for landing." Finally, the words I have been waiting for. Everyone on the plane has returned their seats to an upright position, and those of us looking out of the window see a darkened sky as the plane fast approaches Rio de Janeiro. The flight from Munich, Germany, has taken 12 hours and while many passengers are visibly exhausted, the sight of Brazil's former capital, the country's second-largest city, is breathtaking. It is 7 pm local time on a day in mid-August, which means that it's winter in the southern hemisphere. But even from up high you can sense Rio's enormous energy, which is palpable even when it's not carnival season. The bird's eye view reveals lights that are different from any place I've visited: a seemingly endless carpet of yellow and orange sparkling dots. Like fire—or liquid steel flowing from the converter during tapping.

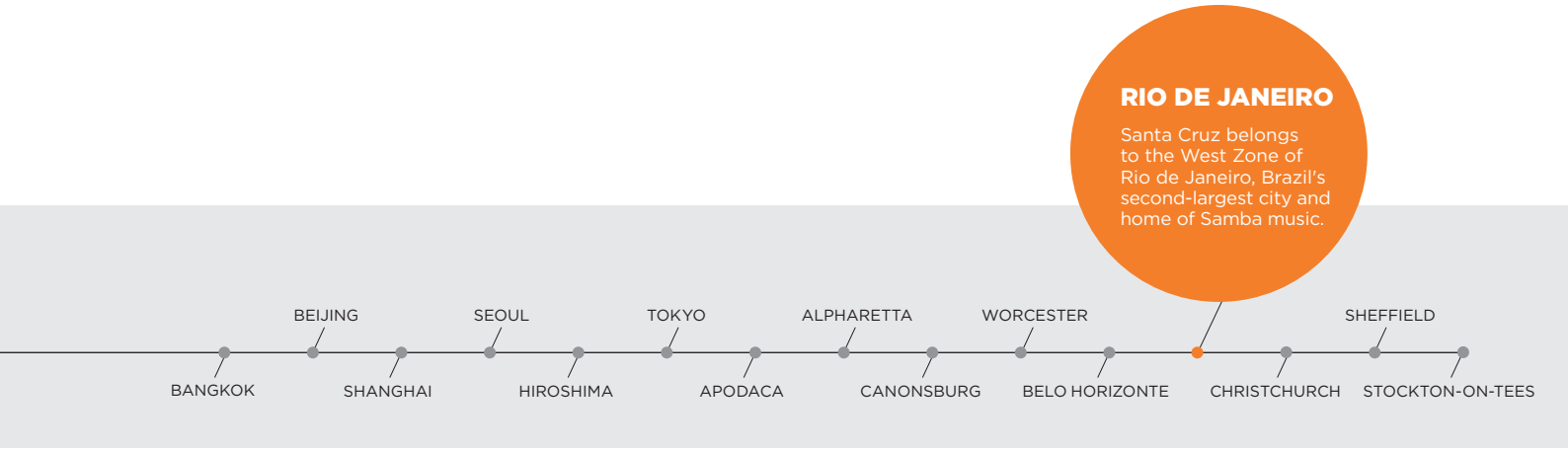
Exiting the aircraft, I catch the scent of Rio for the first time. It is a mix of sea air and a sweeter note of vegetation that I can't quite pinpoint—perhaps flowers or cacti? Humidity levels are substantially higher than those of summertime Continental Europe, making the temperature feel higher than it actually is. People are warmer, too: Even Brazil's border force officers welcome me with a friendly smile, and the taxi driver manages to entertain me with stories from his life (he was born and bred in Rio, the term is "Carioca") even though he does not speak English and I don't understand Portuguese.

My hotel is located in an area called "Recreio" in Rio's West Zone. It is close to the ocean, a beautiful spot, and people are still playing volleyball and enjoying drinks and loud music at the sandy beach. Much too tired from the journey to join the party outside, I immediately take the elevator to my room, take a shower, and soon fall asleep to the sound of booming bass drums.

THE WEST ZONE OF RIO

The next morning, I meet my colleague Paula Santana in the hotel lobby, who will be my guide during my visit of the Santa Cruz company location of Primetals Technologies. She has already ordered a special taxi—special in that the driver is permitted to enter the premises of local steel producer Ternium, a shared site that is also home to Primetals Technologies. Santa Cruz, much like Recreio, is part of Rio's West Zone and features the same coastline. Still, it takes us about an hour to get to the company location, with a brief stop at Ternium's main gate, where security staff meticulously check our identities and authorizations.

Just before we arrive at the company location, Santana and I spot dozens of slabs and enormous raw-material storage areas. "Those are fairly recent," she says. Ternium must have upgraded its logistics, and, as a result, the Primetals Technologies complex feels even more immersed in the immediate reality of metals production. Our destination, the main office building, is a »



3-storey structure. Santana gives me a quick guided tour. Everyone is working in air-conditioned environments, which makes life easier in the Brazilian winter and especially in summer, when temperatures regularly exceed 40 degrees Celsius. As we pass the office of CEO Eberhard Karnitsch-Einberger, I realize that he has left his door open. "Tom, come in," he says, and explains to me that he hardly ever closes his door. "It is a signal to my team that I am always available if they need me." Open and compassionate communication, he explains, is one of the pillars on which the work culture at Primetals Technologies Brazil rests, and the CEO must serve as a role model.

"Have you visited our workshop yet?" Karnitsch-Einberger asks. I have not. "The workshop is the cornerstone of our service activities, which are at the core of what we do here in Santa Cruz," he says. "Not everyone in the steel industry understands the value of the next-level services we provide," the CEO continues. "There is still the misconception that we only provide spare parts. The reality is that we play an important role in the day-to-day operations of the steel producers we partner with. For instance, we make sure that Ternium's continuous casters are always in optimal shape, and we will point out any production-relevant aspects that could be improved. It is a very deep collaboration, and our customers benefit from our metallurgical expertise. With some of our service contracts, we are paid per ton of steel produced. We therefore have a keen interest in keeping things running as smoothly as possible."

TOURING THE WORKSHOP

Curious, I head off to the workshop. Karnitsch-Einberger has arranged for workshop manager Hasley de Almeida to accompany me through what will turn out to be the largest Primetals Technologies workshop I have visited to date. The site is divided into two sections, the first of which is geared toward caster maintenance and has expanded its scope quite considerably in recent years. "We are now able to execute practically every facet of caster-component reconditioning," de Almeida says, and he shows me a finalized part so evenly made that it could belong to a statue. "This is a component of a caster mold," he explains, "and while we do buy in the pipes from a third party, all other manufacturing steps are done here."

Whenever they receive equipment from steel producers for reconditioning, everything first runs through a thorough quality check. Based on this assessment, workers will perform precisely the procedures required to

TOURING THE WORKSHOP AT THE RIO DE JANEIRO LOCATION

Workshop manager Hasley de Almeida proudly shows off one of the spare parts reconditioned by his team. Processing steps include welding and machining.

These rolls are used in continuous casters and need to be disassembled, treated on a parts basis, put back together, and tested. Bearings are particularly work-intensive.

Center bearings of caster rolls must be replaced every time a roll is serviced, but side bearings can often be reconditioned. Here, we see the assembly of a bearing.

upgrade the part to "as new" condition. De Almeida directs my attention to seven enormous caster rolls, which apparently were recently serviced for steel producer Gerdau. "We may be located on Ternium's site and have an extensive and long-standing partnership with them," he says, "but they are not our only customer." De Almeida and his team also keep plants of Gerdau, CSP, CSN, Usiminas, and ArcelorMittal running, and their list of customers is likely to grow in the years to come.

"Bearings always need to be inspected," the workshop head explains, and he takes me to a special testing station. A colleague wearing a huge pair of headphones is touching the rolls, which are slowly rotating, with something that looks like a high-tech magic wand. "This process is an in-house development," de Almeida explains. "You see, the bearings at the center of the roll need to be replaced every time we do a service. But side bearings may be used for two cycles, depending on wear. With this testing station, we determine the condition of the side bearings by listening to the sound they make." After this initial examination of the rolls, they are dismantled and, piece by piece, restored to perfect condition. This includes steps such as welding and machining. Once the reconditioning work is complete, the bearings are put back together again. The inner parts of the bearings are checked in detail using a large magnifying glass with a built-in lamp. It's a lot of manual high-skilled labor. "We have recently started to use different, more technologically advanced components for the bearings," says de Almeida. "They are called 'XLL,' which is short for 'Xtra Long Life,' and are giving us great results." We watch another worker reassembling a bearing, and I find it remarkable how "new" the serviced part looks. De Almeida and I continue our journey through the workshop, and as we turn the corner, we see almost a dozen caster segments lined up, waiting for the reconditioned rolls to be reinstalled. How many of them can the workshop handle per month? "It depends on the circumstances, but I would say up to eight," de Almeida reveals. He is a busy man.

A NEW LIFE FOR COPPER PLATES

Of course, caster rolls are only one aspect covered by the workshop. Copper plates for the caster mold are another: they come in various sizes and with or without thermocouples, which let operators monitor the heat distribution inside the mold. They too are first disassembled and then reconditioned on a parts basis. The process involves submerging the plates in a nickel bath. De Almeida and I walk up the stairs to the seven »

Carlos Eduardo Gomes is a man of many meters. His job is to make sure that measurements taken at the workshop deliver the right results. It is very delicate work.

This is the housing of a bearing, which is undergoing a digital check. Workshop workers use Faro laser technology to verify that the part's dimensions are correct.

Cassiane Oliveira Martins is the operator in charge of handling the "T-800," an advanced robotic welding machine. Rumor has it that the "T" stands for "Terminator."

nickel-plating tanks the workshop is using. They are each filled with a green solution that facilitates the electro-deposition process. "Most plates stay in the tank for around six days," de Almeida says. He explains to me that the resulting nickel layer makes the plates more resistant to wear and increases it lifetime. The chemistry of the solution in the tanks is a critical factor and is continuously kept in check. In fact, just next to the tanks, I discover a small laboratory that monitors the active ingredients in the solution. Like any high-end chemical lab, it is filled with test tubes of all shapes and sizes and lots of electronic measuring equipment. Two staffers are entering test results into the lab's IT system.

ONE WORKSHOP, MANY LABS

The workshop actually has more than one lab. In order to determine the quality of the cooling nozzles used in caster segments, the staff have developed a dedicated spray test facility. The first step in testing a nozzle is to mount it onto a special water pipe that hovers above a meter-long grid that features dozens of slots—all inside a tank made of metal and glass. The setup is completed by a camera, all rugged-looking and likely built for maritime use. Three, two, one, go: One of the workers flips the switch, and water comes bursting out of the nozzle. The crucial question is exactly how much water ends up in each of the slots of the grid underneath—it's about the distribution of the liquid. This is what the testing station reveals. The result is then compared to benchmarks by a computer system, which lets workers examine everything on a single screen. Only the good nozzles make it back into the caster segment.

De Almeida next takes me to the workshop's second section, which is dedicated to "offline" procedures—machining, mostly. Among the powerful equipment designed for processes such as drilling and turning, we find a small booth that houses the calibration lab. Inside, Carlos Eduardo Gomes, a maintenance electrician, is busy checking and adjusting some of the

WHAT MAKES ME **PROUD TO BE BRAZILIAN ...**

Employees of Primetals Technologies share many passions, such as pioneering new solutions for their customers. But every location also has unique qualities. In this section, we catch a glimpse of what makes Brazil so special.

"Brazilians are very innovative people. We use our creativity to support others and become more efficient. In our professional lives, we apply this skill to make our customers happy."

Pedro Elias
Process Engineer

"We are a very empathetic nation. Every day, you can observe someone helping a stranger in the street. I recently had a phone conversation during a train ride. When I told the person that they had just been chosen for a role at the company, everyone on the train celebrated the new employee's success."

Camila Dias
HR Analyst

meters used by his colleagues. Gomes relies on a selection of digital and analog tools to ensure that the gauges remain reliable little mirrors of reality. Some of his tasks require a good set of fine motor skills, and I get the impression that working with meters, much like assembling watches, is a craft all of its own.

INTEGRATING DIGITAL SOLUTIONS

As de Almeida and I continue to explore the workshop, I notice an area marked with the sign "Qualidade 4.0," which translates as "Quality 4.0." The name reminds me of the term "Industry 4.0"—was that the intention? "Yes," says de Almeida. "It is our goal to capture as much data as we can early on, and in digital form. We can measure components as they come in, and even more importantly, as they leave the workshop. It is a quality control measure and allows us to keep track of the precise condition in which serviced parts are sent back to the customer." The team decides to give me a demo. "This is a Faro arm," de Almeida says, pointing to a sophisticated-looking digital measuring device. I realize that I have seen this kind of device before when I reported from the Sheffield company location. However, de Almeida's team uses the arm in a way that's entirely new to me. Not only do they rely on the arm's point-measuring function, but they also examine parts by activating the built-in three-dimensional laser scanner. The latter is quite a sight and has a futuristic feel to it, with the arm emitting blue and red light beams. After a fast scanning procedure, the entire spare part has been captured and can be studied in virtual form on a Windows computer.

Digitalization is taken very seriously at the Santa Cruz workshop. De Almeida introduces me to Hugo Veiga, who orchestrates the location's Industry 4.0 efforts. Much of his work is based on the Maintenance and Asset Technology solution (MAT) developed by an international team based in Linz, Austria, and other company locations. Veiga's role is to implement »

"Brazil is a large country and I love traveling and exploring the many different regions. I particularly value the beauty of our nature, cities, and culture, which are outstanding."

Cassiane Oliveira Martins
Welding Machine Operator

"There is a lot of solidarity in our society, which is something I really appreciate. I also like our tropical weather."

Marcelo Vieira Barbosa
Senior Safety Technician

"We had to overcome substantial challenges in recent times, such as the pandemic and political hurdles. I am proud of the fact that we came out of this period as a stronger nation."

Thiago de Oliveira Martins
Nurse

MAKING DIGITAL TOOLS **UNIVERSALLY ACCESSIBLE**

Hugo Veiga is the Santa Cruz location's industrial digitalization coordinator. He aims to capture information right at the source.

What, in your view, will be the biggest challenge of the metals industry going forward?
Hugo Veiga: We are at a point where we must learn to use our resources in the smartest way possible. Making our processes sustainable will be an important challenge. Plus, digital solutions will connect technologies and people much more comprehensively than ever before. One objective will be to combine human intelligence with artificial intelligence.

How much more digital can metals production become?
Veiga: To me, the main purpose of digitalization is to be able to connect with customers and suppliers, establishing one big network. This digital collaboration will make businesses more agile, transparent, and reliable. So there is no choice, we all have to become much more digital enterprises.

Are there any aspects to Brazilian culture that facilitate innovation and technological progress?
Veiga: It is part of the Latin mentality to adapt well to new situations. We are highly creative and can deal with unexpected scenarios. When you innovate, you often start from scratch and have only few points of reference in terms of where to go, so this quality comes in handy. Every time is different from the time before, therefore you must improvise, have good ideas, and find new solutions.

MAT at the Santa Cruz workshop and to expand its capabilities. "Would you like to learn more?" asks Veiga. We walk back to the site's main office building. Veiga, who always carries a tablet computer, turns on his PC and opens PowerPoint. "Here, you can see all the data sources we are currently using," he says, "and the ones we will be adding in the future." Among those sources, Veiga not only lists the customers' spare parts and workshop tools, but also third-party equipment and something he calls "MAT Mobile." Veiga smiles: "I love the name, it's so close to the 'Batmobile.' But its purpose is quite serious. It is a solution we are creating to let workers input information as they get it. This streamlines our workflows and ensures that we have a complete digital record on every single spare part we service." The data is then securely stored in a customized cloud-computing setup and made accessible on various visualization devices. It's a strong concept, and Veiga says they are making good progress, incrementally building the system on a module-by-module basis.

Karnitsch-Einberger's office is close to Veiga's, so I decide to check if his door is still open. It is. "Tom", he welcomes me back, "what did you think of the workshop?" I tell him that I was impressed with its size and the diversity of tasks executed. Karnitsch-Einberger gives me a smile of recognition. I sense that he is quite proud of his team's capabilities, but there is something else he wants to highlight. "Diversity," he says, "is actually a key principle here in Santa Cruz. "It's very important to me that people feel valued at Primetals Technologies Brazil, regardless of skin color, gender, or age. We recently hired a new welding machine operator, she's in her early twenties, determined, and one of our best staffers."

LAND OF THE FUTURE

Embracing diversity, says Karnitsch-Einberger, is crucial to future-proofing a business. The same is true of energy efficiency and the circular economy. "A little while ago, we swapped all our light bulbs for LED lights," he says, to show that bringing about change does not have to be hard. "We have also drawn up a new waste-management strategy. Everything we once used to throw away, in our offices and the workshop, is now collected, sorted, and handed over to recycling companies. These days, we earn some 7,000 euros a month from selling recyclable materials." It is this forward-looking mindset that Karnitsch-Einberger likes to implement in every aspect of the Santa Cruz location's agenda. The shirt he wears has "Next-Level Services Now" stitched on it. "This is not just a claim," he says. "This is really what we stand for—focusing on what's next." A native of Austria, Karnitsch-Einberger has lived in Brazil for 18 years and has grown to love the country. "Do you know Stefan Zweig, the novelist?" he asks. "In 1936, Zweig wrote that Brazil was the land of the future. I believe this is even more evident today." I think I understand the CEO's conviction. It's about making a meaningful contribution—to a better tomorrow.

A DAY IN THE LIFE OF BIANCA VICENTE DOS SANTOS

As part of the series "Visiting the Company Locations of Primetals Technologies," we sit down with one employee of the respective location—with the aim of illustrating what a regular work day is like for them.

BIANCA VICENTE DOS SANTOS
Administrative Assistant

START OF DAY

05:30
I wake up and prepare my coffee to go. Then, I quickly get dressed and leave the house, all within forty minutes.

06:20
I walk to the nearby bus stop, where the company bus picks me up. During the ride, I usually study for the management courses that I'm taking at college. Sometimes, I also check Social Media.

07:15
After arriving at the company, I have breakfast at the coffee area and chat with my colleagues before proceeding to my office. Afterward, I go through my emails and start working on the purchase requisitions for the day.

08:30
I am part of the team that takes care of employee travel arrangements. On some days, I receive urgent requests to reserve hotel rooms or book flights for someone. I tend to put other tasks on hold and process travel requests immediately.

10:00
I go back to the purchase requisitions. For those that were already processed by the purchasing department, I will make the required preparations so that they can be forwarded to the colleague who makes the payment to the respective party.

12:00
I also process travel expenses and do the accounting. I make sure that my colleagues get reimbursed for any payments they may have made on their business trips.

12:30
This is the time for lunch. We have a new canteen on site where we get fresh food from a buffet. I often have entertaining conversations with my colleagues over lunch, so it's also an important social part of my day.

14:00
End of my lunchbreak. I get back to work and go through various kinds of correspondence, both internal and external in nature. So, for instance, if a colleague or a department receives a letter from a partner company, I will make sure it gets delivered to the correct person.

14:30
Another one of my responsibilities is to maintain our printers: I ensure that there is always enough paper left.

16:57
This is the precise time when I leave the Primetals Technologies office building and jump onto the company bus.

17:30
I arrive at the college, where I am taking my management courses. The courses only start at 7 pm, and I will use the time in between to study or to do a bit of shopping.

21:40
End of my college courses. I take another bus, which will take me home.

22:20
I finally arrive at home, prepare dinner for my son and myself, and talk with my son about how our days have been.

23:30
I take a shower, get myself ready for bed, and enjoy a good night's sleep.

EXPERIENCING THE LOCATION
AND THE RIO DE JANEIRO AREA

MAN- AND WOMANPOWER

Diversity plays a central role at the Santa Cruz company location of Primetals Technologies. People of all genders are welcome, and tasks that were traditionally assigned to one of the sexes (such as welding or nursing) are simply given to the most qualified person. This mindset greatly contributes to the overall team spirit of the place, which leads to a shared sense of community. The wall art decorates the backside of the main office building and is meant to serve as an inspiration to everyone.

CRISTO REDENTOR

The Christ the Redeemer statue is arguably the most iconic and widely known of Rio's landmarks. It was constructed between 1922 and 1931 by a French-Brazilian team of architects and engineers. Cristo Redentor is 30 meters tall, with the statue's pedestal adding another 8 meters to its height. The original design had Christ holding a globe and a cross in his hands but was later changed to the open arms.

PÃO DE AÇÚCAR

Sugarloaf Mountain was named after the form in which sugar was produced and sold in the late 19th century: a tall cone. The mountain rises 396 meters above Rio's harbor and is accessed by cable car.

WORLD-FAMOUS BEACHES

While the Copacabana beaches have risen to greater fame than the ones found in Recreio (pictured), they all have a lot in common. The sand is soft, the water clear—much to the enjoyment of locals and tourists.

THE CARNIVAL

There is no bigger carnival in the world than the one held in Rio de Janeiro on a yearly basis since 1723. You do not have to dress up in a super-extravagant manner to participate, as our photo illustrates.

PIONEERING SUSTAINABILITY **FOR BUSINESS AND PEOPLE**

Eberhard Karnitsch-Einberger is CEO of Primetals Technologies Brazil and responsible for four company locations, including the one in Santa Cruz. Originally from Austria, he first joined the Primetals Technologies predecessor company VAI aged 18 as a student employee. He has since lived and worked in the U.S.A., Italy, and of course Brazil, where he has spent 18 years now and still enjoys walking on the beaches of Rio de Janeiro.

How would you describe the wider agenda of the Santa Cruz company location?
Eberhard Karnitsch-Einberger: First and foremost, Santa Cruz stands for exceptional expertise in caster maintenance. Every single day, we support our customers in running their operations as smoothly as possible. Our contribution is not limited to supplying spare parts. Rather, we are true partners to our customers and add value to their operations thanks to our deep knowledge about the steel-production process. With some of our contracts, we are paid per ton of steel produced—which means that we are sharing both the risk and the reward. We also help our customers to identify any production-related aspects that could be improved.

You recently doubled down on the location's digitalization efforts. What prompted that decision?
Karnitsch-Einberger: In the mid to long term, digital knowledge management tools will become extremely important in the steel industry—for instance, to preserve the knowledge of seasoned operators. We are working on digital tools and processes that let workers input new information on the fly, as part of their routines. As a result, all data is captured very early on.

Do you think that "green" will be an even greater catalyst for change than "digital?"
Karnitsch-Einberger: Yes, provided that governments and financial institutions are incentivizing renewable energy production to a sufficient degree. Hydrogen has the potential to prompt far-reaching technological change. As for the steel industry, our product in principle is the most recyclable material on earth. As our societies turn their attention more to sustainability and the optimization of resources, this factor will be crucial.

It seems to me that you care quite deeply about environmental issues?
Karnitsch-Einberger: You are correct. In fact, I almost chose environmental engineering as my field of study back in the day. I went with business administration and mechanical engineering instead but always felt a strong urge to promote a sustainable lifestyle. This applies to economic decisions but also to interpersonal relations.

What, in your view, are the more relevant environmental trends and opportunities in Brazil?
Karnitsch-Einberger: What we should be working toward much more is circularity—meaning that there are many materials that could be recycled but currently are not. Solar power is still barely used in Brazil, but I do see an upward trend. In the northeast of the country, you will find some wind turbines. Finally, in terms of hydrogen technologies, there are around 20 projects on their way, at various stages of maturity.

How would you characterize your leadership style?
Karnitsch-Einberger: I think leaders must be conscious of the shadow they cast—meaning that your reputation rests upon the way you present yourself and interact with others. Your team will expect positive or negative things from you, and you should try to understand what those assumptions are. Personally, I try to live by Immanuel Kant's idea of the categorical imperative, to act in such a way that you can be regarded a role model.

What innovation should be realized but probably never will?
Karnitsch-Einberger: Fusion reactors. They would let us produce an infinite amount of renewable energy at incredibly low cost. |

WOMEN IN STEEL

GISELLE CONFORT DE VASCONCELOS

Technology Coordinator at Primetals Technologies Brazil

Who are the great women in the world of steel? In this series, we ask them to step into the limelight. The steel industry may long have been a bit more on the conservative side, but this is changing fast. These days, it is only right that Metals Magazine reflect the global trend toward an even more diverse and powerful workforce in steel production.

> **“As my career developed, my personality became even more relevant. These days, it is crucial for me to keep learning and to be open to exploring new things.”**
>
> Giselle Confort de Vasconcelos

How did you get started in the metals industry?
Giselle Confort de Vasconcelos: I studied chemical engineering at the University of Rio de Janeiro and came to Primetals Technologies 15 years ago as a trainee. In my eighth year of working at the nickel plating facility, I was invited to join the development team tasked with improving the nickel plating processes. The project was a success. We were able to increase the quality of the treated plates quite considerably.

What were the specifics of this early project?
De Vasconcelos: I was given one month to determine why some of the copper parts we were treating were showing porosity. I compared the ideal scenario for nickel plating with the operational procedures at the time. It soon became clear that several improvements could be made. The chemical composition of the solution used for the nickel bath was not always optimal.

How did you go about finding a solution?
De Vasconcelos: I created smaller versions of the nickel plating tank to conduct experiments and got great results. We then changed one of the production tanks, and the results were equally good. From there, step by step, the entire facility was upgraded. We also changed many procedures we had in place—filter cleaning, carbon treatment, checking the pH levels, and more. Finally, I instructed my colleagues on how to execute nickel plating so that the new approach would be consistently and properly implemented.

What's your current role at Primetals Technologies?
De Vasconcelos: I oversee all technological aspects of the workshop at the company's Santa Cruz location and was made a Key Expert for copper repair in July 2022.

What is your most recent innovation?
De Vasconcelos: In terms of the nickel plating facility, we are currently working on developing measuring equipment that can determine the thickness of the nickel layer during the coating process—while the copper parts are in the nickel bath. I have visited nickel plating facilities in the U.S.A. and Germany to study this side of the process in greater detail and have the impression that everyone would like to use the kind of device we are working on. We have now completed the drawings and expect to build the first round of prototypes soon.

How important was your training in terms of enabling you to create new solutions?
De Vasconcelos: It is a mixture of personality and training. If the team is facing a problem, we work together toward finding a solution. Our management lets us take ownership and run the necessary experiments. This is how we pioneer new technologies and processes. Having said that, my training was instrumental at the beginning of my career because I needed to apply that specific expertise. As my career developed, my personality became more relevant since I learned more and more about areas that were new to me at the time. Being open to exploring new things is now really crucial. »

> **Having good relationships with your colleagues and project partners is important. When everyone is in a good mood and wants to share new ideas, the outcome is usually better.”**
>
> Giselle Confort de Vasconcelos

Do you work systematically toward new ideas, or do they just come to you “out of the blue?”
De Vasconcelos: New solutions do not come out of nowhere. When I was confronted with the early issues around nickel plating at Primetals Technologies, it was very obvious what had to be done. With the new kind of measuring device mentioned earlier, I had this idea but needed to collaborate with my colleagues to find out how we could design and build such a tool. I would say that both principles are true and should ideally be combined to come up with something that works well.

Are there any “tricks” you use to promote creativity and inventiveness?
De Vasconcelos: Having good relationships with your colleagues and project partners is important. When everyone is in a good mood and wants to share new ideas, the outcome is usually better. An encouraging environment can be a powerful enabler of innovation.

In your view, is creativity something you are born with, or something acquired by training?
De Vasconcelos: I think that some people are born creative and then—for instance—become artists. Most regular people also have a creative side but need to hone their skills, branch out, and learn new things. This is especially true when complex processes are involved. Metals production, of course, is full of complexity.

What is the main source of inspiration for your work?
De Vasconcelos: I think I was born with the desire to make things better—promoting change comes naturally to me. But I also like to surround myself with people who are driven to improve the reality we live in.

Do you see innovation as the result of the work done by certain outstanding individuals or by a larger group of collaborators?
De Vasconcelos: The larger group. There is nothing more impactful than the combined experience and knowledge of a group of exceptional people. Complicated problems are almost always too big for any one person to resolve on their own.

Is there any new technological area—outside of metals production—that you are fascinated by?
De Vasconcelos: Yes, the field of medicine. A lot of progress is currently being made with medical equipment, especially related to surgery. Operations can now be performed from hundreds of kilometers away. Also, the development of the Covid vaccines—especially the speed with which they were created—is incredible.

Can you name any inventor, scientist, or entrepreneur that you admire?
De Vasconcelos: There are so many! Albert Einstein of course—he is a great one—but also Nils Bohr, Marie Curie, Earnest Rutherford, ... the list goes on!

What’s next for you, and what are the projects you are currently working on?
De Vasconcelos: There are two major welding-related projects concerning caster equipment. We want to automate our welding operations even more. Currently, there is still a substantial amount of manual labor involved. Our aim is to automate almost every aspect of the welding process and to achieve ever higher levels of product quality for our customers and partners. |

WHERE IT ALL STARTED ...

Giselle Confort de Vasconcelos' first steps into the metals industry began at college, where a teacher explained to her the inner workings of a steel plant. She immediately found metallurgy fascinating and began to think about a career working with blast furnaces. However, in her last year of studying chemical engineering, she heard that Primetals Technologies was operating a nickel plating facility in Rio de Janeiro's Santa Cruz area and got in contact with the company. The rest is history: de Vasconcelos dramatically improved the way the location's nickel plating tanks were run, making a major contribution to the quality of the metallurgical services provided by the Santa Cruz workshop.

NEXT-LEVEL WELDING

Having made a name for herself in the field of nickel plating, de Vasconcelos was given the opportunity to branch out and take responsibility for additional aspects of the processes executed at the Santa Cruz workshop. She saw the development as a chance to continue learning new things and to make additional improvements to processes and workflows—something she cares deeply about. The photo to the right shows de Vasconcelos standing next to a new welding machine she was instrumental in acquiring and integrating into existing workshop procedures. The machine is called the "T-800," and the team likes to joke that the "T" stands for "Terminator." It's a powerful device.

IMPROVING THE WORKSHOP

The projects that de Vasconcelos executed in her first 15 years at Primetals Technologies were so successful that she was promoted to "Key Expert" for copper repair in July 2022. Nickel plating remains close to her heart, but these days, her responsibilities go far beyond the field of nickel plating alone. In fact, she is currently in charge of all technological aspects of the workshop. De Vasconcelos oversees all of the workshop's processes, ensures that new solutions are implemented swiftly and properly, and keeps pushing the limits in terms of the overall capabilities of the workshop. It is a busy life that she leads, but her track record clearly shows she would not have it any other way.

EVERYDAY STEEL

STEEL IS A PART OF OUR ENVIRONMENT, BOTH INTERIOR AND EXTERIOR

Steel is one of the most versatile materials in the world. It makes up much of our devices, vehicles, buildings, and infrastructures. But what about areas where steel may go unnoticed in our day-to-day considerations of steel? In this series, we look at various examples of how steel has become a part of our world—in the most conspicuous and inconspicuous ways. Here, we explore steel in our homes and offices and how it supports us as we sit, stand, work, entertain, and dine—that is, steel in our furniture.

Weissenhof Chair (Weißenhof-Stuhl, 1927), designed by Mies van der Rohe and upholstered by Lilly Reich

Marcel Breuer's Cesca Chair (1928) combines chrome-plated tubular steel with woven wicker, an iconic part of his furniture designs. Other versions are also without arms and appear similar to the cantilever chair by Mies van der Rohe.

Steel is an undeniable part of our modern landscape. It has been molded and shaped to form monumental objects that make up our cities and support our infrastructures and smaller constructions that even support us as we recline. For artists and designers, steel symbolized the future, an inherently modern material. Designers found ways of combining steel and other materials to produce comfortable objects. These objects made their way into our homes, offices, and buildings, and have become a part of everyday furniture design.

A HISTORY OF FURNITURE

As an integral part of furniture, steel has more likely gone as something relatively unnoticed in our daily lives. Look around your workplace or home, and you may be surprised to find just how much metal surrounds us and supports us as we work, eat, and recline at the end of a long day. Steel in furniture goes beyond the typical use of screws and joining elements or accessories but can make up entire furniture pieces. While aluminum is often associated with modern furniture, steel has and continues to play a significant role in furniture design. However, this was not always the case.

At the end of the 19th century, artists and designers began to experience the first instances of mass production of everyday objects. Regarding materials, furniture was dominated by wood, richly lacquered, and embracing bent shapes and layered pieces. Workshops, such as the Wiener Werkstätte—founded in 1903—pushed the limits of craftsman design. After World War I, industrial design and manufacturing shifted. With industrial materials coming into fashion, the founding of the Bauhaus in 1919, and the emergence of their form following function mantra, tubular steel became an integral part of furniture design.

BEYOND ICONIC: THE CHAIR

Although chairs, stools, loungers, couches, and the like are as ubiquitous as steel, it may often go unnoticed that many of them are true masterpieces of art and design that surround us in our everyday lives. Moreover, it may also be striking how many of our most iconic and commonplace pieces of furniture have their foundation in design principles inspired by the modern material of steel. This article's images highlight steel's prominent, subtle, and tactful use in chairs.

MODERN COMFORT IN STEEL

Perhaps the most recognizable steel element in furniture is chrome-plated tubular steel. What's more, the application of this material has solidly found its place in the design of reclining furniture. Bauhaus professor Marcel Breuer famously utilized tubular steel in his B3

chair, later known as the Wassily Chair, and a breakthrough in functional design.

Other designers who utilized chrome-plated tubular steel include Mies van der Rohe and Mart Stam. It also made its way into Eileen Gray's E-1027 table and Charlotte Perriand's LC4 chaise longue. However, as time went on, steel in furniture returned to support elements, and during World War II, the use of aluminum and plastics began to gain prominence. By the 1960s, plastics overtook steel in furniture design and showed the most significant potential for mass production.

ELEGANT DESIGNS

While plastics, laminate, plywood, and aluminum diversified the various materials at one's disposal for furniture design, steel has remained a steadfast element since the early 20th century. The association with steel as a cold material has often kept it outside of homes and relegated its presence to offices, professional environments, or outdoor furniture. Still, these objects remain crucial elements of comfort and modern design.

Even the modern office chair was conceived with the support of steel elements. Steel as a solid structural material has also given way to its incorporation into dramatic designs, often highlighting its unique strength.

In recent years, steel has reemerged in furniture design, from shelving to office furniture to functional works of art. Part of the inspiration for such contemporary works returns to the mid-20th century, as wood and plastics gradually replaced steel. The mass adoption of aluminum, wood, and plastics afforded certain freedom to explore steel aesthetically. One such experiment is the wire chairs of Harry Bertoia, dating back to 1952. The Bertoia Diamond chair pushes the limits of investigating space by using a wire frame that creates a crisscrossed diamond pattern. Today, elegant pieces of designer furniture surround us in our daily lives beyond Bertoia's concept. And while tubular steel furniture may be most common in an office waiting room or corporate lobby, the representative and inherently modern character of chrome-plated steel tubes remain a fixture of contemporary society. |

Bertoia Diamond Chair (1952) is an exploration of space and steel in a unique piece that creates something comfortable out of the industrial material.

Marcel Breuer's Club chair (model B3) (1927-1928) has striking curves combined with the canvas elements allow the individual to "float" in tubular steel.

WOMEN IN DESIGN

While names such as Walter Gropius, Marcel Breuer, Le Corbusier, and Mies van der Rohe often ring in the ears of modern design enthusiasts, brilliant women were equally a part of early 20th-century avant-garde movements. They were behind some of the most well-known pieces in the design world. Here are just two examples of women in design.

EILEEN GRAY
(1879–1976)

An Irish furniture designer and architect, Eileen Gray represents one of the 20th century's most profound contributors to modern architecture and furniture design. Active primarily in France, Gray made a name for herself with geometric abstraction and the incorporation of exotic woods, lacquers, and even animal skins. In 1923 at the Salon des Artistes Décorateurs, her pieces provoked scathing reviews among French colleagues but were hailed by Dutch designers. With publications in the Dutch journal "Wendigen," Gray attracted the attention of Walter Gropius, and at the Salon d'Automne, she met and became friendly with Le Corbusier. During the mid-1920s, Gray started integrating contemporary materials into her furniture, including tubular steel, aluminum, and glass. These materials are prominent in her villa on the Mediterranean coast, called "E-1027." Perhaps one of the most famous pieces of tubular steel and glass furniture from the last century is the E-1027 Adjustable Table. While applying glass and chromed steel tubes is exceptionally modern, it is also possible to see Gray's desire for multi-functionality. The strength of the steel tubes also allows for the table's unconventional design. Eileen Gray would then continue to design apartments and villas. Later in life, she extended her experiments with materials to the world of plastics.

LILLY REICH
(1885–1947)

Although Lilly Reich was born in Berlin, her status allowed her to study in Vienna und Josef Hoffmann in 1908 at the Wiener Werkstätte. Returning to Berlin, Reich studied decorative arts under Else Oppler-Legband, an expert in fashion, needlework, window decoration, scenery design, and interior design. After her first commission in 1911, Reich joined the Deutscher Werkbund in 1912, an institution with close ties to designers and artists at the Bauhaus. In 1924, Reich met architect Ludwig Mies van der Rohe (for more on Mies van der Rohe, see "Mies van der Rohe: The Architect of Cities Made From Steel and Glass" on pages 96–101). Following this fateful meeting, Reich would go on to collaborate with Mies for nearly a decade. Their collaboration resulted in her appointment as the Bauhaus' head of the weaving workshop from 1932 to 1933. While Reich's work was primarily in upholstery and interior design, her contributions to steel in furniture come with the unique design of the Weissenhof Chair from the Weissenhofsiedlung in 1927 and the Brno Chair for the Barcelona Pavillion in 1929. The simplicity of both chairs is a testament to Mies van der Rohe's "less is more" philosophy, but the brilliance of the design's simplicity is also the interaction between the chromed steel elements and the natural materials. Combining wicker, in the case of the Weißenhofsiedlung Chair, and leather, in the case of the Brno Chair, Reich emphasizes the balance between the modern world and the natural. Reich's career would effectively end in Germany after 1933. Towards the end of her life, she dedicated her time and interests to re-establishing the Deutscher Werkbund and the education of a new generation of designers.

GREAT PIONEERS
THAT INSPIRE US

Portrait of Mies van der Rohe by Hugo Erfurth, 1934

At Primetals Technologies, we constantly strive to pioneer new and groundbreaking solutions for the steel industry. We work with passion, inspired by our colleagues and partners around the world. Another source of inspiration are the great pioneers that have come before us—innovators who have made a profound impact on the way we live and changed the course of history. In this series, we look at the life, the challenges, and the achievements of some of the most outstanding pioneers of all time.

TIMELINE

1886
Born Maria Ludwig Michael Mies March 27 in Aachen, Germany, the son of a marble worker, Michael Mies, and Amalie Rohe.

1899
Mies attends the Spenrath-schule, the trade school, in Aachen for two years. After dropping out seeks to hone his own skills in practice.

1891
Worked as an apprentice at local building sites and then four years in several Aachen ateliers focusing on ornamentation.

1907
After moving to Berlin in 1905, impresses Peter Behrens with the Alois Riehl House. Meets Walter Gropius and Le Corbusier.

1922
Submits his design for a steel and glass skyscraper for Berlin's Friedrich-straße.

MIES VAN DER ROHE
THE ARCHITECT OF CITIES MADE FROM STEEL AND GLASS

A fixture of the metropolis worldwide, the skyscraper has become a symbol of the modern city. Towering steel and glass structures disappear into the clouds reflecting the sky itself. The history of the skyscraper and our great cities is part of the history of modern design. Among their champions, including Frank Lloyd Wright, Le Corbusier, and Walter Gropius, stands Ludwig Mies van der Rohe.

From his humble beginnings as the son of a stonecutter, Mies van der Rohe would become one of the defining influences of what is known as "International Style." As the name indicates, this global phenomenon of post-war architecture spread globally, bringing steel, glass, and concrete to skylines in a grand fashion. Unlike many of his friends and colleagues in architecture, who later shifted away from International Style, Mies remained true to his belief in the freedom afforded by steel and glass.

THE FIRST SKYSCRAPER

Mies' journey until the design of his first skyscrapers began after his move to Berlin in 1905. While working as an apprentice under Bruno Paul, Mies completed his first independent commission, a house for Alois Riehl—a philosopher and university professor. The design impressed architect Peter Behrens, the leading German architect, graphic, and industrial designer most known for his work with the Allgemeine Elektricitäts-Gesellschaft (AEG). Peter Behrens' office attracted the likes of Walter Gropius and Le Corbusier, with whom Mies woud remain acquainted throughout his career. Despite his claims of frustration working for Behrens, Mies took many of the principles of Behrens' designs and early twentieth-century architecture with him.

Following World War I, Mies returned to Berlin to find the city buzzing with the Avant-Garde movements »

DID YOU KNOW ...?

- ... the tallest steel skyscraper in the world is the Willis Tower in Chicago, completed in 1974, which uses the same structural principles as the Burj Khalifa in Dubai, currently the tallest building in the world.
- ... construction projects account for more than 50 percent of global steel demand, including structural steel, reinforcing bars (rebar), and sheet products—not to mention the steel used as part of the heating and cooling equipment and even interior fixtures.
- ... structural steel is often the material of choice for environmentally conscious architects. For example, structural steel produced in the U.S.A. contains 93 percent recycled scrap; almost all of that steel can be recycled at the end of a building's lifetime.
- ... corten steel, or korten, produces a self-protecting rust layer or "patina." Corten steel is also weathering steel and is often an aesthetic choice for architects and designers who want to use the matured rust color as part of their design.
- ... while iron dominated the construction industry, Bessemer steel began to make headway with large projects during the 1880s, including the Brooklyn Bridge in New York and the Home Insurance Company Building in Chicago.

1929
Art director for the German Pavillion alongside interior designer Lilly Reich at the Barcelona International Exposition in 1929

1938
November 20—Armour Institute of Technology celebrates the new head of their architecture program

1958
Completion of his most accurate realization of his original skyscraper designs, the Seagram Building, Manhattan, New York

1968
Completion of the Neue Nationalgalerie in Berlin, health in rapid decline

1969
Died August 17, age 83, six weeks after Walter Gropius

SKIN-AND-BONES

BARCELONA PAVILION (1929)

Working alongside interior designer Lilly Reich, the German Pavilion, or Barcelona Pavilion, quickly became one of Mies' most known works. Presented at the Barcelona International Exposition in 1929, Mies wanted to create a space of refuge from the international event. One is drawn into the space by creating a smooth flow from the interior to the exterior through its striking glass windows and low-hanging roof. Book-matched marble allows the natural materials to stand out against the chrome-plated steel columns of the interior, drawing the eye to a small courtyard hidden away from the larger reflecting pool. No matter how you approach the Barcelona Pavilion, each turn around every corner simultaneously reveals the novel and familiar, framing the interior and exterior alike.

FARNSWORTH HOUSE, PLANO, ILLINOIS, U.S.A. (1951)

Completed in 1951, the Farnsworth house, named after Dr. Edith Farnsworth, contains eight I-shaped steel columns and supports the roof and floor framework. The one-story house, designed as a weekend retreat, stands out in a wooded area, and its striking glass walls place one immediately in nature. While the house may not be an ideal design in terms of privacy, it is difficult not to feel taken aback by the beauty of its presentation or how it thrusts oneself into the surrounding natural beauty.

NEUE NATIONALGALERIE (NEW NATIONAL GALLERY), BERLIN, GERMANY (1968)

Completed just a year before his death, the Neue Nationalgalerie in Berlin is the pinnacle of Mies' revolutionary designs with steel. Most striking is the floating sensation of the massive 65-square-meter coffered roof held by eight steel pillars outside the glass façade. The result of this design meant the interior space gave way to an enormous feeling of openness. Despite several frustrations with the building as an exhibition space later, the Neue Nationalgalerie is a prime example of International Style and Mies' skin-and-bones architecture.

> **“I think steel is a fine material. By fine, I mean it is very strong. It is elegant. You can do a lot with it. The whole character of the building is very light. This is why I like it when I have to build a building in a steel construction.”**
>
> Mies van der Rohe
> Conversations with Mies van der Rohe (2008) by Moisés Puente

of Expressionism, Constructivism, de Stijl, and the newly founded Bauhaus. Immersed in the vibrant art and design culture, Mies met artists and graphic designers, including Theo van Doesburg and El Lissitzky. In 1921, Mies participated in a competition to design a high-rise office building on Friedrichstraße in Berlin. His design was dismissed due to its unusual choice to cover the entire building in a glass "curtain."

The design reflected Mies' concept of "skin-and-bones" architecture, which hinged on the idea that the steel skeleton could free the exterior walls from their load-bearing function. Mies was inspired by structures being built in the United States and found the exposed steel skeletons had a sublime effect. Although this design would never come to fruition, Mies' concept would influence his later projects.

THE FUTURE OF ARCHITECTURE

The impact of Mies' concept for the skyscraper rests in its pioneering vision for solid structures, freeing up space and creating an interplay between the interior and exterior of buildings. His cooperation with various organizations, notably the Deutscher Werkbund (German Work Federation) and CIAM (Congres Internationaux d'Architecture Moderne), would help expand his status as a world-renowned architect. As his notoriety grew, he was invited, alongside Lilly Reich (for more on Lilly Reich and her impact, see Everyday Steel: Steel in Furniture Design, pages 92–95), to work as the artistic director for the German section of the Barcelona International Exposition in 1929.

Known as the "Barcelona Pavilion," Mies once again shook the architectural world with his elegant, sleek, and open design. The Pavilion strikes a balance between interior and exterior space, reminiscent of the glass façade in his skyscraper design, using glass to reveal the inner structure of the building. Here, the Pavilion's low roof and large glass windows create a series of frames through which one experiences this dramatic piece of architecture. The materials of the Pavilion are also essential and broken down to the fundamentals of architectural design, that is, marble, steel, chrome, and glass. The beautiful interplay of manufactured and natural materials makes the Pavilion a reflection of the future of architecture.

STEEL IN ARCHITECTURE

After the Exposition in 1929, Mies would run the Bauhaus from 1930 until 1933. In 1938, Mies emigrated to the United States and became the head of the architecture program at Armour Institute of Technology, later Illinois Institute of Technology. In the United States, Mies' interest in steel as a material and its incorporation into his designs would flourish.

After his exhibition at the Museum of Modern Art in New York in 1947, Mies was commissioned by Herbert Greenwald, a developer, to design several apartment buildings in Chicago. Amongst them are perhaps two of the most famous buildings in Chicago today, 860 and 880 North Lake Shore Drive. By today's standards, the 26-story apartment towers on Lake Michigan are perhaps not what comes to mind regarding skyscrap-

SKYSCRAPER

860-880 NORTH LAKE SHORE DRIVE, CHICAGO, ILLINOIS, U.S.A. (1951)

Tucked along North Lake Shore Drive are two subtle features of the Chicago Skyline and the masterful achievements of Mies in the U.S.A. Creating his 26-story apartments out of steel and concrete, Mies realized his concept of "skin-and-bones" architecture. Hovering above their ground floor plazas, the steel exterior—painted in black—frames the windows of each floor without giving away the interior content. Instead, the steel and glass exterior allow passersby to contemplate the building's interiority while grasping the volume and freedom of the space within. With the canopies floating above the entrance and backlit opaque glass on the first two floors, the two buildings are beacons inviting their residents home and sheltering them before even entering the building. A surprising warmth stems from Mies' steel and glass apartments.

SEAGRAM BUILDING, NEW YORK, NEW YORK, U.S.A. (1957)

Following the North Lake Shore Drive apartments, the Seagram Building on Park Avenue in Manhattan was the first realization of Mies' glass skyscraper. His intentional choice to move the building back from the street allows visitors to grasp the entire structure as they approach. Mies enclosed the building in metal but placed an ornamental brass I-beam on the exterior of the building to reference the structural materials within the building and draw the eye upward. For Mies, the building itself was more than just another building, but a representation of a building as sculpture, a work of art in architecture.

TORONTO-DOMINION CENTRE, TORONTO, CANADA (1969)

Finished a year after his death, the Toronto-Dominion Centre is a cluster of downtown Toronto, Canada, buildings whose unique dominating black-painted steel and bronze-tinted windows reflect Mies' commitment to "International Style." Although he only worked as a consulting designer, each of the towers, including those added in 1974, 1985, and 1991, all share Mies' original design. Framed by structural steel, including their inner workings—that is, elevators, stairs, washrooms—the most striking feature, mimicking the Seagram Building in New York, is the bronze glass "curtain" framed by painted black steel and exposed I-beams.

ers, but their exposed steel elements and glass façade began to realize Mies' 1922 ideas. The exposed steel elements reflect the interior structure of the building, playing with interior and exterior spaces and putting the structural steel skeleton on display amongst pieces of reflective glass that shield the interior from immediate interpretation.

"LESS IS MORE"

The twin North Lake Shore Drive apartment buildings were just the beginning of Mies' realization of the skyscraper. Less than a decade later, Mies' gained the opportunity to design and construct a building in New York City. The Seagram Building is set back off of the famous Park Avenue in Manhattan by a beautiful and intentional plaza. The drama of the building's design is in its reserve, allowing people to experience its verticality as they approach it across the famed marble plaza. With windows framed by dark brass I-beams representing the interior steel skeleton, the brass complements the marble of the plaza, drawing one's eyes upward. The Seagram Building reveals the minimalist character of International Style and harmony between interior and exterior space. The 38-story building embodies Mies' philosophy of "less is more," favoring simplicity and highlighting the structure itself for its aesthetic presentation. Although Mies was not the inventor of the phrase "less is more," it was a motto he would often recite, particularly to his students.

Today, the impact of Mies' pioneering ideas is as undeniable as universal. Despite the late twentieth-century critique of International Style, architects still value Mies' concepts of construction and the interplay between interior and exterior space. One can easily see Mies' impact in the playful transformation of "less is more" into "Yes is More" by BIG architect Bjarke Ingels. Inspired by the minimalism of Mies' designs, Ingels took the concept of an interplay between interior and exterior and the natural and the manufactured one step further. Ingels' designs often take the urban and industrial landscapes and transform them into recreational oases. For example, CoppenHill or Amager Bakke in Copenhagen rearranged the equipment of a waste incineration facility and placed a functional park, ski slope, and much more atop the facility, designed to turn a previously uninviting industrial area into an urban retreat.

From Mies' focus on steel and glass to ski-slopes on power plants, architectural transformation and what was once revolutionary in the early twentieth century has now come much further. While Mies' drawn skyscrapers never came to fruition, glass-curtained towering skyscrapers are now part of every metropolis. Architects like Ingels take Mies' concepts and principles one step further, pioneering the future and extending the interplay between interior and exterior, manufactured and natural, and steel and the environment. |

FRIEDRICHSTRASSE SKYSCRAPER (1921)

Although his original design for the Friedrichstrasse Skyscraper would never come to fruition, his proposal for a building surrounded by glass on a skeletal steel frame would define a great deal of his architectural aesthetic. This project was Mies' first experiment in the metropolitan setting and he wasted no time in causing a stir with his dramatic design. Designed for a triangular site near the Spree River in Berlin, the "Honeycomb," as Mies would call it, pushed the boundaries of glass and steel architecture. His goal was to wrap a steel skeleton with a glass curtain, revealing the structure itself to passersby. The beauty of his design was also a stark contrast to the buildings he felt were rampant in the Berlin metropolis. The glass monolith would shine like a beacon amidst buildings overburdened by ornamentation. His design anticipated the future of our great metropolises, where cities of steel and glass are now commonplace.

PETER ÖRTELT ...

... started working in the metals industry in 1996 and has since brought much insight and innovative spirit to Primetals Technologies and to its customers.

IN THIS SPECIAL INTERVIEW FORMAT, WE ASK AN EXPERT FROM PRIMETALS TECHNOLOGIES TO USE THEIR IMAGINATION.

Peter Örtelt heads the Integrated Plants division at Primetals Technologies, which puts him firmly at the intersection between business consultancy, strategic planning, metallurgy, and plant-logistics optimization. Örtelt has become one of the go-to specialists for the Metals Magazine team whenever complex, multi-disciplinary topics arise. It is, therefore, with some delight that we this time feature Örtelt—and his personal view on *what if* ...

> **“Many larger steel producers are currently striving to optimize their global footprint, in terms of carbon emissions but also simply on a cost basis.”**

... THE WORLD'S NATIONS STARTED TO SEE EVEN GREATER VALUE IN HAVING A LOCAL STEEL INDUSTRY?

Peter Örtelt: This is one of two opposing trends in our industry. For some producers, it makes sense to focus on local markets rather than on exports—and to prioritize a reduction in carbon emissions and costs. On the other hand, there is also a trend toward increased consolidation. Certain multinationals aim to further secure production-related advantages using "economies of scale" principles. One interesting strategy is for large cooperations to build "upstream hubs." These hubs would put the more energy and raw-material intense steps of the production chain—basically, all ironmaking—into regions where the resources required can be obtained at relatively low cost. For example, Australia is well-positioned to build upstream hubs thanks to its vast amounts of ore deposits. Now, suppose solar power has become even more prominent in the country. In that case, the ore could be turned into hot-briquetted iron or pig iron using green energy because the solar energy could be used to produce hydrogen—and hydrogen could then serve as the reducing agent at the ironmaking stage. I could see countries like Japan buying the resulting products in large quantities, but setups like these are always dependent on mutual political will.

... CONSOLIDATION IN THE STEEL INDUSTRY CONTINUED AT THE CURRENT PACE—OR EVEN INTENSIFIED?

Örtelt: If we look at the companies that provide raw materials to the steel industry, we see a landscape of only a few conglomerates, which are highly relevant, and of many smaller independents. As is often the case, larger corporations dictate the pricing. You can observe this phenomenon in the steel industry, as well, and this is one reason why carmakers often use two or three suppliers rather than just one—it puts them into a better negotiating position, or, in a less bad one, since there is only limited room to maneuver, to begin with. What the larger companies all have in common is that they currently strive to lower their global footprint, in terms of carbon emissions but also simply on a cost basis. Consequently, it may make sense to execute the ironmaking and steelmaking processes in one region and turn the resulting intermediate products into value-added goods elsewhere. Overall, the steel industry's large companies have several advantages over the smaller ones: they can exert greater political influence—for instance, via lobbying—and they have an easier time securing their interests in terms of raw-material procurement, market position, pricing of goods, and ensuring business continuity in a changing world.

> **"The world's societies need to rethink globalization and find consensus based on a greater sense of urgency regarding environmental matters."**

... THERE WAS ANOTHER GLOBAL SUPPLY SHAKE-UP? SHOULD WE ALL HAVE BETTER CONTINGENCY PLANS?

Örtelt: I think we are experiencing the aftermath of a shake-up of global supply chains at present, and companies are reacting to the new situation as best as they can. The last few global crises—such as the housing bubble, Covid, and the climate crisis—have made apparent the flipside of globalization. Shake-ups also impact not just the metals industry but also other sectors—pharma; for instance, when the whole world is dependent on India for vaccine production, some nations may feel highly vulnerable to supply-chain constraints. Understandably, they would look for alternatives or additional suppliers to become as resilient as possible. Heavy industry—our sector—must take supply chain woes particularly seriously because of the scope and size of the projects it realizes. If you know that, in the event of a delayed order fulfillment, there is a penalty to pay, any supply-chain problems affecting key components or items with longer lead times can be quite unnerving. Penalties are why many companies in the steel business are currently re-evaluating risks and adopting new strategies. Sometimes, they will choose an "economies of scale" setup, with lower prices but fewer suppliers and more risk. Other times, they will diversify.

... NEW GOVERNMENTAL REGULATIONS EFFECTIVELY RENDERED INTEGRATED STEEL PRODUCTION OBSOLETE?

Örtelt: In many regions, the reality is that producers have started to move away from integrated steel production. There are several reasons for this development, but governmental regulations—those that already exist and those that are expected to come into force—certainly play an important role. In the long term, integrated plants will have to be modified so that the ironmaking aspects can be executed much "greener" way. Greener means that production units such as the coking plant, sinter plant, and blast furnace will be replaced, with the option of moving the ironmaking side of production to areas with large raw-material deposits and readily available and cheap energy. However, if a producer chooses to distribute different production steps to different countries, they will have to deal with multiple governments—each with its own political agenda and lifetime. COP27, the 2022 climate conference held in Egypt, clearly demonstrated how hard it can be to reach an agreement that is satisfactory to the international community and individual governments alike. I do believe, though, that our societies need to rethink globalization and base any consensus on an increased sense of urgency regarding environmental matters.

... STEEL PRODUCERS INCREASINGLY GOT INTERESTED IN HYBRID STEELMAKING? WHAT ARE THE CHALLENGES?

Örtelt: First off, we should clarify that the term "hybrid steelmaking" is used in the context of the transformation of the integrated steel plant and involves the introduction of electric steelmaking to the traditional production route. Adding an electric arc furnace is not without its challenges: The obvious issue centers around power consumption, especially since a large EAF is required to reach the desired capacity. The electrical grid needs to provide much more energy than before, and the EAF's power supply must interact with the grid in a "clean" manner. But even if the capacity of the furnace was chosen correctly, integrating it into the existing logistics setup and production scheduling is the next challenge. The tap-to-tap time of a converter—a BOF—is often shorter than that of an EAF. Also, changes to secondary metallurgy are often needed, as well, if any losses in overall production volume are to be avoided. A core question is on how to achieve continuity: "How can we keep producing the same steel grades as before?" Especially when relying on high scrap rates, it is mandatory to use extremely well-sorted scrap for the production of higher-end grades. Finally, adding an EAF will affect some by-products, with less metallurgical gas resulting from the process, which must be compensated for.

... ELON MUSK, JUST HAVING TAKEN OVER TWITTER, DECIDED TO GET INTO RENEWABLE HYDROGEN PRODUCTION?

Örtelt: In the early 90s, when I was still a metallurgy student, hydrogen-powered technologies were regarded as the cornerstone of the future of steel production. Thirty-three years later, it seems that not much has changed—hydrogen is still a far cry from being mainstream. But I do think that we are all feeling increased pressure to take hydrogen seriously. So, to answer your question, if someone like Elon Musk were to successfully lower the cost of hydrogen production—and it would have to be green hydrogen made using renewable energy from sources such as solar and wind—it would definitely propel metals production forward. As an industry, we would then have the chance to move away from coal completely. Hydrogen can already be used as a reducing agent. For instance, direct reduction technologies may rely on natural gas today, but they could relatively easily be converted to being run on hydrogen. So the core problem is really the availability of green hydrogen and not that of the solutions required to make good use of it. Those already exist. Now, if Musk—who is new to the field of metals production—arrived with fresh, disruptive ideas, it could expose some of the industry's blind spots regarding hydrogen and lead to a push in the right direction—with a new and innovative approach.

meta.ls/pioneers-talk06

PIONEERS TALK #6:

STRATEGIZING THE FUTURE OF METALS PRODUCTION

If you find Peter Örtelts thoughts intriguing, you may appreciate the 14-minute "Pioneers Talk" session we recorded with him as our guest. In this video, Örtelt openly shares his insights into strategic planning, production routes, logistics, and more. Scan the QR using your mobile device or follow the link to the left.

HOW WILL WE LIVE?

MY CARBON FOOTPRINT: HOW CUTTING-EDGE TECHNOLOGIES WILL HELP US KICK THE CARBON HABIT

What will tomorrow's world look like—a world that has implemented the innovations pioneered today? A world based on the groundbreaking technological, social, and political ideas that have only just surfaced? In this series, Metals Magazine's independent editor James Gray takes a peek into his crystal ball and lets us know what the future holds.

Over the last few years, there has been growing emphasis on "going green." The phrase refers to striking a balance between the life you lead, the impact of your life choices on the planet, and being mindful enough to help maintain ecological balance. Our planet is growing at an unsustainable rate, with the global population expected to hit 9.8 billion people by 2050. At that rate, it would take two planets to support current consumption.

However, in 2020, an unexpected development unfolded when U.S. greenhouse gas emissions fell by around 10 percent, primarily as a result of self-isolation during the Covid pandemic. This unforeseen change of events represents the largest drop in greenhouse gas emissions since World War II. Leading the decline was the transportation sector, where emissions dropped a massive 14.7 percent against 2019 levels as people travelled less. Power plant emissions witnessed the second largest decline, dropping 10.3 percent below 2019 levels. In a way, Covid showed that our actions as individuals can make a significant difference in lowering our effective carbon footprint. The question is, what more can we do?

> **“Covid prompted the largest drop in greenhouse gas emissions since 1945. This proves that our actions as individuals can make a significant difference in lowering our carbon footprint. The question is, what more can we do?”**

Studies show that 20 percent of greenhouse gases are generated by households. In fact, most of an individual’s carbon footprint will usually come from transportation, food, and housing. But if we’re to have any chance of preventing substantial climate change—which means avoiding a two degrees Celsius rise in global temperatures—, we will need to reduce our carbon emissions to under two tons per person by 2050.

A SMARTER LIFESTYLE

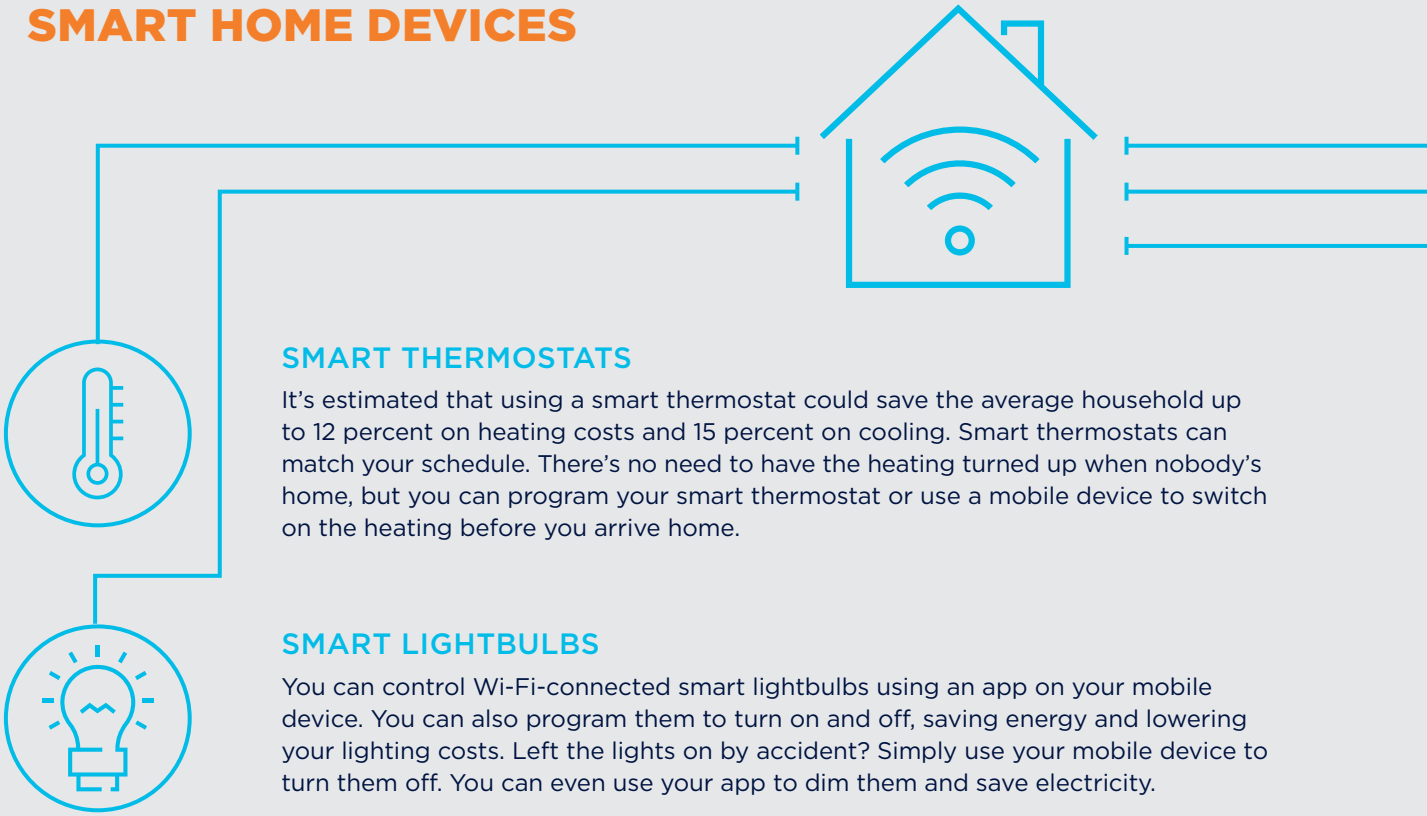
One of the easiest ways to reduce your carbon footprint is by using smart devices. These use Artificial Intelligence (AI) to learn your routines and habits as time goes on. They can also track and monitor your home to improve energy efficiency. Smart devices such as thermostats and home appliances are usually connected to the internet via Wi-Fi or Bluetooth. This allows you to control them using a smartphone or tablet. Left for work or vacation and forgot to turn off the lights? No problem with an app on your mobile device.

Some smart devices can learn your day-to-day routines using AI. For example, smart water heaters can track your hot water usage. Let’s say you do your laundry or prefer to take a shower in the evening. Your smart water heater will adjust its heating times to match your schedule, so that less energy is used to keep the water hot throughout the day. If your utility providers have off-peak tariffs, AI-based smart scheduling can reduce energy consumption and save you money. »

DID YOU KNOW ...?

- ... that an internet connection via 4G has twenty times more impact in terms of energy use compared with Wi-Fi? This is because high-speed communication technology via mobile networks places considerable demands on base stations.
- ... that storing an email emits 10g of CO_2 on average per one year’s storage, which is equivalent to a light bulb turned on for one hour? So empty your trash and delete emails you no longer need!
- ... that inactive browser tabs still consume energy even if they are not being viewed? You can try using a browser extension that suspends the activity of a tab after a given period of time.
- ... that streaming accounts for more than half of the world’s internet traffic through subscription services such Netflix, Amazon Prime, and platforms like YouTube? Try watching fewer videos or downloading music onto your phone rather than streaming it.

5 WAYS TO SAVE ENERGY WITH **SMART HOME DEVICES**



SMART THERMOSTATS

It's estimated that using a smart thermostat could save the average household up to 12 percent on heating costs and 15 percent on cooling. Smart thermostats can match your schedule. There's no need to have the heating turned up when nobody's home, but you can program your smart thermostat or use a mobile device to switch on the heating before you arrive home.

SMART LIGHTBULBS

You can control Wi-Fi-connected smart lightbulbs using an app on your mobile device. You can also program them to turn on and off, saving energy and lowering your lighting costs. Left the lights on by accident? Simply use your mobile device to turn them off. You can even use your app to dim them and save electricity.

FIG. 1: Smartening up your home is an important means of lowering your individual carbon footprint.

Home devices like smart meters can also communicate with modern electric grids, forming a complex network. Two-way communication between smart grids and smart devices can help to ensure that energy is delivered more efficiently. Artificial Intelligence is a game-changer. AI can quickly sift through vast amounts of data to recognize patterns and make predictions. Think about how Netflix suggests shows based on your past viewing. It's the same kind of technology. Climate scientists have jumped on the technology and are adapting it to predict climate change.

SWITCH TO GREEN ENERGY

Renewable energies are becoming increasingly accessible and affordable. Energy providers are now offering greener tariffs and by switching to a company that provides electricity from renewable energy—that is energy that comes from continually replenishing sources—you can reduce your household emissions and save money on your utility bills. Solar, wind, or hydroelectric energy are good examples. A 100 percent green supply means that all the electricity you consume is "matched" by purchases of renewable energy—such as wind farms and hydroelectric power stations. With more and more people switching to renewable energy, investment in these technologies is increasing and eventually renewable energy prices will fall.

If you're unable to switch home energy supplier, you can still make changes to reduce your dependence on fossil fuels. For instance, you can install solar panels or a solar water heater, or use solar-powered tech like outdoor or portable lighting or mobile phone power banks.

There are also steps you can take to reduce household energy consumption. For example, try installing only LED lights in your house and choosing energy-efficient appliances and heating and cooling solutions. Make sure your home is properly insulated with appropriate heat trapping or cooling materials. This will reduce the

SMART PLUGS

If you don't have a full smart home setup yet, smart plugs are a good place to start. They work by plugging into any electrical outlet. You can then control the energy consumption of whatever you plug into them. Using apps, you can also program times of use or turn appliances on and off remotely.

SMART APPLIANCES

Yes, even your kitchen appliances can talk to you. Left your refrigerator door open? It will let you know via an app on your mobile device. Gremlins in the washing machine? Get notified of the problem and repair your appliance quickly in order to avoid the expense of a completely new washing machine.

SMART SPRINKLERS

Maximize water usage and cut your water bill with a smart sprinkler system. These systems use real-time weather data and set your lawn watering time to match. So you won't have to worry about watering your lawn during a downpour or end up with underwatered grass on a hot, dry day.

amount of energy needed to warm or cool your home, which is both kinder on the planet and your pocket.

CAN WE STILL EAT MEAT?

Experts agree that cutting down on meat—red meat in particular—is a better choice for the environment. Why? Because the production of red meat involves the use of so much feed, water, and land. Plus, cows themselves emit methane, a harmful greenhouse gas. According to the figures from a comprehensive scientific study conducted in the last couple of years, meat and dairy account for just 18 percent of our calories and 37 percent of our protein intake, the livestock footprint takes up 83 percent of farmland, and meat and dairy production is responsible for 60 percent of agriculture's greenhouse gas emissions.

One way to address this obvious inefficiency is to actually grow meat in the laboratory. Lab-grown meat solves the land use problem while still allowing meat to be consumed. Food tech companies are exploring different ways to produce beef and seafood, for example, from animal cells. No need to raise livestock—or rely so heavily on feed, water, fertilizers, and fuel. Growing meat and fish in a lab involves taking cell samples from animals and extracting stem cells, which have a high reproduction rate. The cells are then treated with a protein that promotes tissue growth. A bioreactor—think of it as an artificial womb—is used to maintain the proper environmental conditions to support tissue growth. The new cell tissues can then be attached to a scaffold mesh so that three-dimensional steaks and fillets are formed.

Reducing our carbon footprint isn't a new concept. But given the emerging technologies geared toward more sustainable, cleaner living, it's becoming much easier for individuals to save energy and help to erase some of the damage. This is an exciting time to start putting your love of technology to good use to reduce your carbon footprint—in order to leave this world in a better state for future generations. |

NEW TECH HELPING TO TACKLE **GLOBAL WARMING**

What are some of the ways that businesses can offset the rise in emissions or even achieve carbon neutrality? From the vehicles we drive and the fuel we use to power them to the way we manufacture products or grow our food, greenhouse gas emissions are a constant concern. Here are just a couple of emerging technologies.

FUEL ADDITIVES

Fuel additives can be used to enhance performance, for example by improving the capabilities of your vehicle's engine. They can also be used to stabilize fuel to keep it in a functional condition while being stored for extended periods. Fuel additives can help save fuel, reduce emissions, prolong engine life and boost the cleanliness and performance of gasoline, diesel, and bio-fuel.

HYDROGEN-POWERED VESSELS

According to Marine Digital, the global shipping fleet accounts for 2.2 percent of global CO_2 emissions. What's more, big ships burn tons of low-quality "bunker fuel" that can pollute the air with toxic particulates. A partnership between Scandinavian nations is building a ferry to connect Oslo and Copenhagen by 2027. It will be powered by hydrogen fuel cells that create energy from hydrogen gas and release only water. The ferry will avoid 64,000 tons of CO_2 annually.

HYDROELECTRIC DAMS

It can be a challenge to site large-scale solar installations in densely populated countries. Floating solar installations on hydroelectric dams can exploit unused aquatic surfaces, and a new floating solar plant in South Korea will be the world's largest at 41 MW. The Korean plant will provide power for 60,000 people. But with more than 150,000 square miles of man-made reservoirs world-wide, floating solar has a "potential on a terawatt scale," according to the World Bank.

GREEN CEMENT

It's estimated that the world uses four gigatons of cement per year in construction. Limestone needs to be heated to over 2,700 degrees in a chemical reaction that releases huge amounts of CO_2. One company, Solidia, has developed a "green cement" technology that allows cement to be fired at lower temperatures, slashing emissions by one third. The technique cures concrete using CO_2 gas, which is embedded in the concrete. Solidia claims that if its technology were adopted industry-wide, it could lower annual CO_2 pollution by 1.5 gigatons and save 3 trillion liters of water.

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GET READY FOR GREEN STEEL

The steel industry is currently undergoing a deep transformation toward more environmentally friendly production processes, especially in the iron- and steelmaking areas. The ambition is to get closer to the vision of green steel, which is made using renewable energy and following circular economy principles. While transitioning to green steel will be the industry's biggest success factor, it also poses many challenges, which need to be met both commercially and technologically.

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